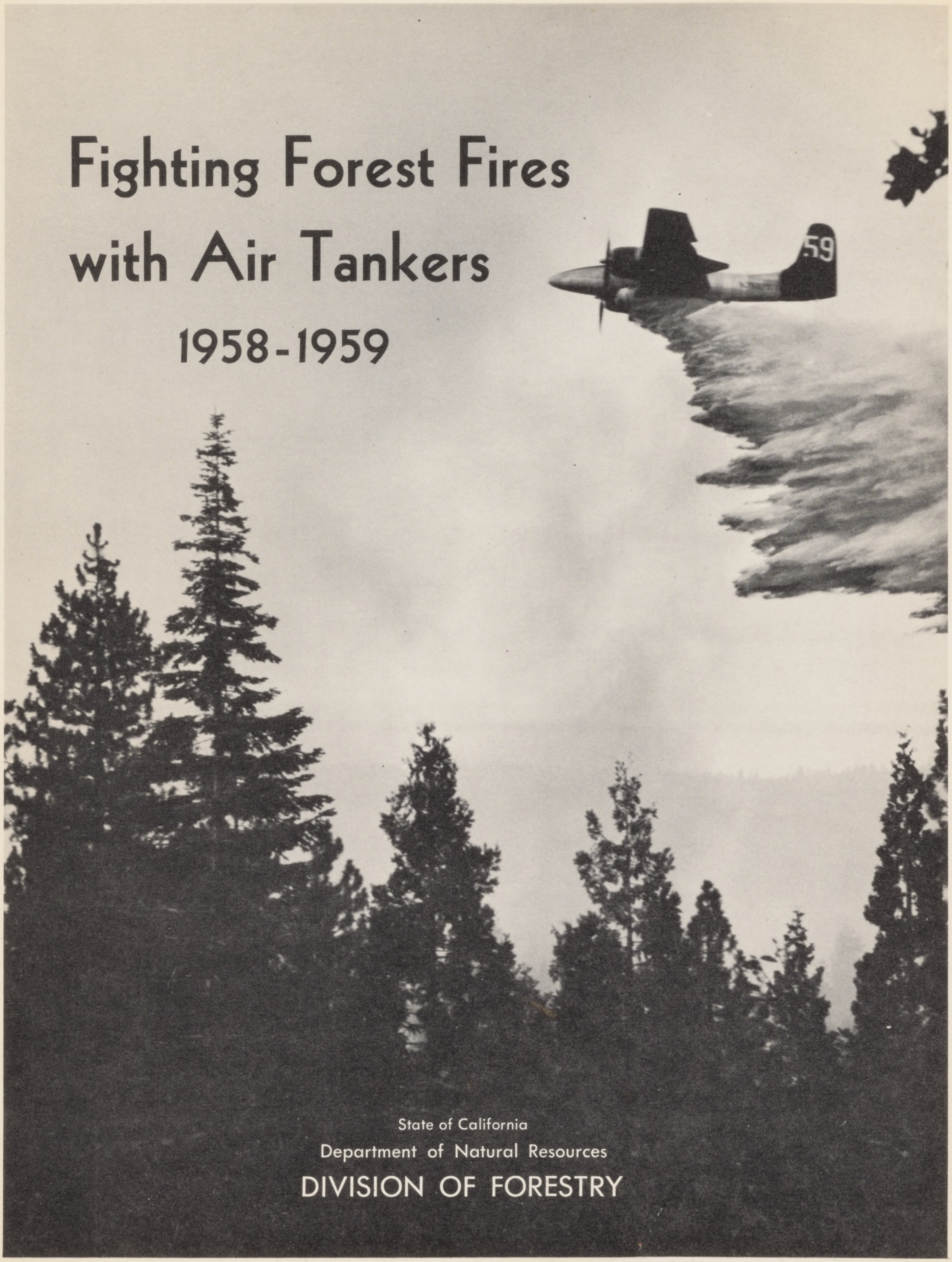

Fighting Forest Fires with Air Tankers

1958-1959

State of California
Department of Natural Resources
DIVISION OF FORESTRY

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Governor
Edmund G. Brown

Director,
Of Natural Resources,
DeWitt Nelson

F. H. Raymond
State Forester

FIGHTING FOREST FIRES WITH AIR TANKERS

PART ONE: 1958
by H. P. Reinecker

PART TWO: 1959
by C. B. Phillips

effort expended by field personnel in the compilation of many forms and records.

This document covers a two year period. It is divided into two parts--one part representing each year as prepared by different authors. For this reason the reader may notice a difference in style and method of presentation. While the parts could have been molded into one, it was felt that each part (and year) represented a certain entity in itself worthy of separate preservation.

Other fire control agencies have been engaged in developing and using aircraft in the initial attack of forest fires. The California Division of Forestry has worked in close cooperation with such agencies in respect to both the study and the practical application of this new tool. The report presented here does not pretend to acknowledge the full benefit derived from such mutual cooperation. It should be accepted simply as the carefully evaluated opinion of this one agency in respect to the integration of a new technique into its fire control system.

F. H. RAYMOND
STATE FORESTER

FIGHTING FOREST FIRES

WITH AIR TANKERS

PART ONE: 1958

by H. P. Reinecker

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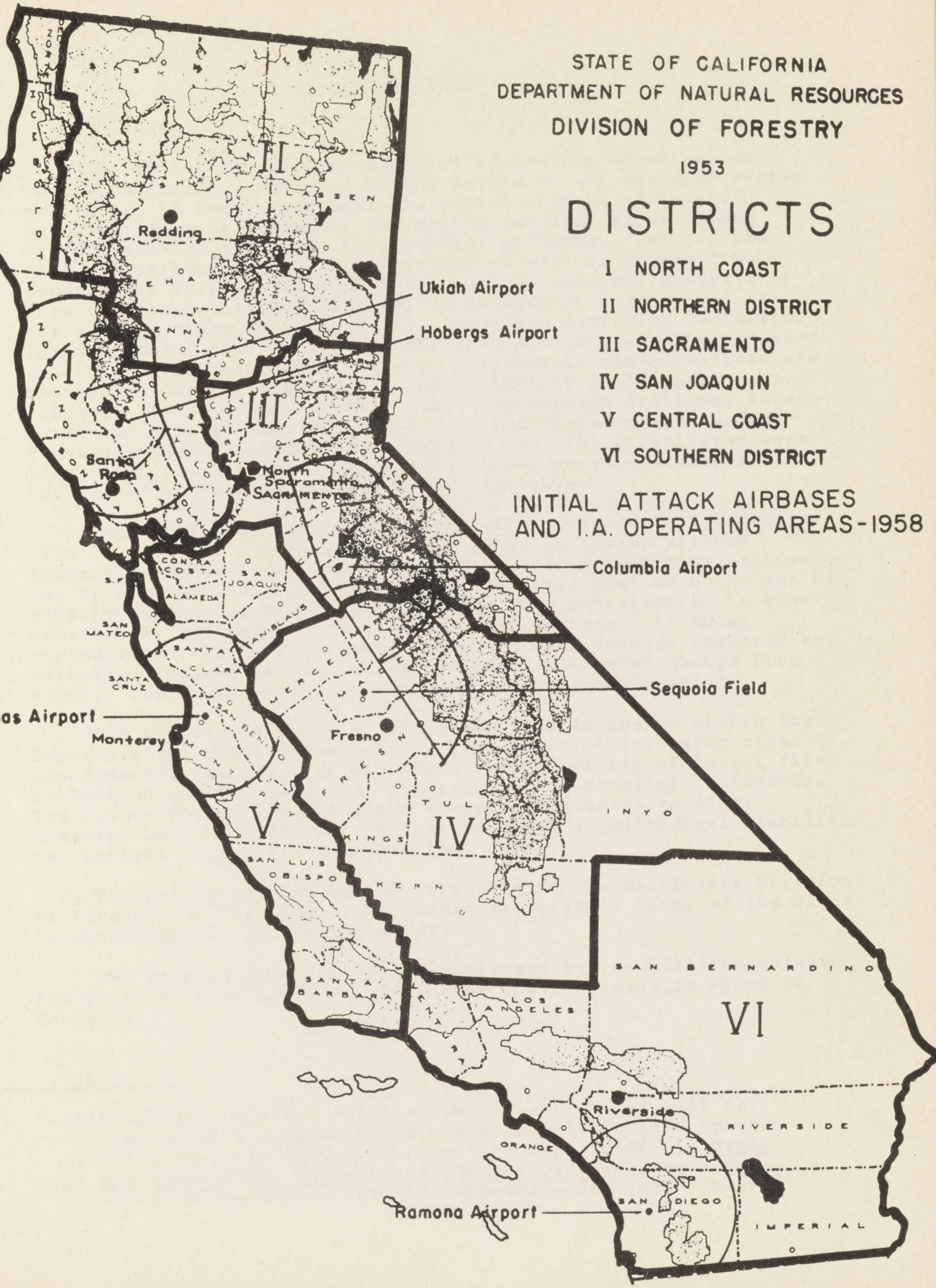
STATE OF CALIFORNIA
DEPARTMENT OF NATURAL RESOURCES
DIVISION OF FORESTRY
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INTRODUCTION

The efficiency of a forest fire protection organization can be partially identified by the nature of its pre-suppression activity. It seems reasonable to expect that an efficient organization will foster an aggressive research effort aimed towards solving its major fire control problems - both in the fire prevention phase of fire control as well as in the fire suppression area of effort. There must be constant analysis of fire incidence patterns in order to accomplish a reduction of hazards and risks where possible. Adequate detection facilities (ground and/or air) need be established and consistently reviewed in light of changing fire history. Dependable communications are required. Current maps must be maintained of fuel types, water sources, risks, access routes, etc. Suppression stations, access roads and similar facilities must be constructed where needed. Personnel must be hired and trained to meet the anticipated work load. And, lastly, the suppression forces must be equipped with the latest and most efficient tools available.

The final measurement of an effective fire control organization lies in the record achieved in reducing losses without increasing excessively its expenditures. If forest fire incidence can be progressively reduced and if the fires that do occur can be quickly suppressed with a minimum loss, the organization is then effectively meeting its fire control obligations. If total expenditures are in a favorable ratio to both damages incurred and potential damages (values which would be endangered should fire occur), the organization is also operating economically.[1]

The California Division of Forestry is an agency within the Department of Natural Resources. This Division is, among other assignments, charged with the basic responsibility of forest fire protection on the state and private wildland areas of California. The protection of some of these areas is contacted to other agencies and the Division, in turn, assumes a contractual liability for certain lands of other agencies.

The net <u>direct</u> protection furnished by the California Division of Forestry to the timber, watershed and grazing lands of the State is approximately 22 million acres.

The average fire activity experienced by the Division between the years of 1953 through 1957 on the above acreage is shown in Table 1.

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[1] Although the economic implications of air attack will be considered on a limited basis, reference is invited to the Battelle Memorial Institute Report of June, 1958. <u>A Study of the Cooperative Forest-Fire-Control Problem</u>, for a more detailed discussion of the "minimum-cost-plus-loss" theory.

Table 1. Average Forest Fire Record on Direct Protection Area, For the Years 1953 - 1957

Fire Size Class[1]	Burned Acreage	Percent of Total Burn	No. of Fires	Percent of Total No.
A-B	1,970	1.9	1,553	79.4
C	9,236	8.7	279	14.3
D	10,383	9.7	63	3.2
E	84,869	79.7	61	3.1
TOTAL	106,458	100.0	1,956	100.0

1 Size Class A: 0-.25 acre; B: .26-9.99 acres; C: 10.0-99 acres, D: 100.0-299.99 acres; E: 300.0 acres and over.

In briefly interpreting Table 1, it appears that the California Division of Forestry's initial suppression action might be considered highly effective on nearly eighty percent of the fires attacked. Its action is reasonably effective another fourteen percent of the time. On the remaining six percent of the fire starts, however, effectiveness of initial attack is non-evident since it is on this small percentage of fires that nearly ninety percent of the total annual area loss occurs.

The wide disparity noted above coupled with the recent development of a new fire suppression tool, the <u>air tanker</u>, led to the proposal that this new tool be employed on an experimental basis in an effort to reduce the percentage of fires which normally occur in the larger size classes. Thus, if the Division could single out and stop only twenty percent of those fires which have the potential of reaching the D and E size classes (<u>one percent</u> of the total fires attacked), the reduction in acreage loss could conceivably be <u>fifteen</u> percent of the present average annual acreage burned.

As the objective, the Division attempted on a large, planned basis the integration of <u>air initial attack</u> with initial attack by standard ground forces. Contracts were entered into with the operators of eleven aircraft which were modified to assume the role of "air tankers". These planes and their pilots were then placed on standby ready for <u>immediate</u> dispatch to fires in their incipient stage. The air tankers were dispatched as squadrons from six bases and were always accompanied by a light observation plane with a Division employee acting as attack coordinator and observer. Out of 250 dispatch actions by the initial attack tankers, 112 met the criteria established and defined as "initial attack".

This report will consider several aspects of the 1958 air initial attack operational experiment including:

1. Prior research and experience with the use of fixed wing aircraft.

2. The background planning that preceded the actual operations.

3. The manner in which the operation was conducted at the various initial attack locations.

4. A tabulated summary of air tanker action.

5. An evaluation of the air program.

6. Statistical analysis.

7. General Discussion of the 1958 Initial Attack Air Program.

8. Conclusions and recommendations.

PAST RESEARCH AND EXPERIENCE WITH AIRCRAFT AS A FIRE SUPPRESSION TOOL

Use of aircraft for forest fire detection, transportation of fire fighting personnel and delivery of supplies needed on the fire line dates back at least as early as 1919. There is considerable documentation of the effectiveness of such action.[1]

A little known effort occurred in 1931 which perhaps should be identified as the immediate predecessor of current techniques. C. J. (Red) Jensen, now of Sacramento, California, modified a World War I Hispano Suisa with two water tight hoppers located on the outside of the fuselage near the pilot's cockpit. On two occasions during the summer of 1931, Mr. Jensen reports he flew sorties against forest fires burning in Butte County some twenty miles East of Oroville. The fact that this plane could not be flown safely at low altitudes eliminated the possibility of making successful uncontained water drops.

Following this field experimentation which was stimulated only by the far reaching vision and limited finances of a couple of the early commercial flyers, the U. S. Forest Service conducted two rather elaborate research projects.

The first project was conducted largely in California between the years of 1936 to 1939. Studies were undertaken at the Livermore Airport in Alameda County, at the Pilgrim Creek Nursery strip near the town of Mt. Shasta and at the Cuyama Ranger Station strip in Santa Barbara County. This project during its various phases explored the use of many powders such as finely ground clays, dehydrated lime, talc, cement, gypsum, sodium chloride, calcium chloride, fine sand, etc. The effectiveness of certain foaming agents and other chemicals[2], the use of voice amplifiers to aid air-to-ground communications and use of cargo parachutes was also tested. Like the second project to follow in Montana, all attempts to drop various liquid materials on a ground target relied on the concept of confining the materials in an enclosed container. The California project did,

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1 Refer to bibliographical index, works 1, 3, 4, 8, and 11. Further references to articles or items appearing in a specific book or publication will appear in this text as arabic numerals in parenthesis, coinciding with the listing of those works in the bibliography.

2 mon-ammonium phosphate, ammonium sulphate, phosphoric acid, sodium phosphates, potassium carbonate, and sodium acetate.

however, initially propose to make uncontained, or free, water drops. A theoretical study by the Physics Department of the University of California indicated that slip stream effect due to wind and the forward speed of the plane would so break up the falling column of water that none would effectively reach the ground. Further research on this concept was then dropped from the California Project.(10) Other conclusions reached as a result of the California project indicated that foam in five and ten gallon tin containers as well as the chemicals tested were ineffective for fire suppression purposes when applied in containers or as loose, dry powders.

One of the problems recognized at that time lay in the fact that the planes used in those early years were not constructed to safely recover from dives and violent, low-level manuevers. They were declared by the Forest Service pilot-engineer, James W. Allen, in Mr. F. W. Funke's report to be unsafe over woods and rough terrain at low altitudes.(10)

The second major attempt to utilize the airplane as a direct attack tool occurred during the summers of 1947 and 1948 in Montana. The U. S. Forest Service, as in 1919, again teamed up with the U. S. Air Force to test the applicability of the aircraft and bomb sites which had been developed during a war period. The Montana experiments used surplus fuel tanks equipped with fins for better accuracy. The "water bombs" were then dropped in low level "skip-bombing" runs by P-47 Thunderbolts and in high level attacks from a B-29 Superfort and a B-25 Billy Mitchell bomber. Although accuracy showed considerable improvement over the earlier experiments, the hazard to ground personnel was recognized as being too great for field application of either technique.(2)

As in two earlier projects, military activity in the early 1950's again gave impetus to the use of aircraft for forest fire control work. Douglas Aircraft personnel while test flying a Douglas DC-7 in 1953 jettisoned water ballast over a desert area in Southern California. They observed that some water reached the ground in sufficient amount to wet the surface. They then informed county, state and federal forestry officials of this observation. Subsequent tests that year made in cooperation with the California Division of Forestry, Region V of the U. S. Forest Service, the Forest Service Equipment Development Center at Arcadia and the Los Angeles County Fire Department confirmed the fact that when sufficient water (375-500 gallons) was released through a six inch opening at a relatively low height above ground (150 feet, plus) free water drops would dampen the ground surface.(12)

This revelation was shortly followed by the ideas and determination of Major Warren Schroeder, a Marine pilot attached to the El Toro Air Base. He believed (as did Jensen earlier) that smaller quantities of water could be effectively disbursed from the proper type of plane and from properly designed containers. Arrangements were made to demonstrate such a drop in early 1954. After some last minute delays and the substitution of an active marine pilot for Major Schroeder who was then on leave, a low-level drop was made from a Douglas AD-2. A 250 gallon napalm tank was suspended beneath the fuselage. Both ends of the tank were sealed with plate glass. Electric detonators were taped to the glass panes; these were discharged when the plane was over the target. The water used in the test had a foaming agent included upon the recommendation of the base fire chief. A considerable amount of the fluid was observed on the target but principally in the form of bubbles. Actual wetting action was not readily apparent.[10]

This experiment was shortly followed by the 1954 Operation Firestop in Southern California. This was a joint research effort by a group of fire agencies operating within California and the Federal Civil Defense Administration, the Marine Corps, the U. S. Weather Bureau and the University of California. A TBM owned by Paul Mantz was modified so as to carry 600 gallons of water in the bomb bay. A series of drops were made at speeds of about 110 knots and at low altitudes (10, 50 and 100 feet). Heavy drenchings were obtained with a pattern that averaged 90 feet wide by 270 feet long at the 50 foot altitude.[16]

An accompanying experiment involving fire retardents (and reported in Firestop Progress Report No. 4 [17])turned attention to the possibility of utilizing a fire retardent with the water dropped in low level attack. Eventually sodium calcium borate mixed in the ratio of four or five pounds per gallon of water proved to produce a reasonably efficient fire retardent when applied to forest fuels. This development in conjunction with the potentials of low level drops from planes really brought the feasibility of air attack as a fire control tool into proper focus.

Joseph B. Ely, Fire Control Officer on the Mendocino National Forest, visualized the low flying agricultural crop dusting and spray planes as a logical aircraft type for air attack work. By modifying the outlet of a 160 gallon tank installed on a N3N Biplane (World War II trainer) a fairly rapid discharge of water was achieved. A series of tests were then run in 1955 by the Mendocino National Forest, the California Forest and Range Experiment Station, the U. S. Forest Service, Arcadia Equipment Development Center, the California Division of Forestry and the Willows Flying Service. Drop patterns were determined while using loads of both 125 gallons of water and of 100 gallons of Borate-water mixture. When dropping from 30 feet at about 80 miles per hour concentrations were measured ranging up to three gallons per 100 square feet of target. Maximum width of the drop pattern was about 60 feet and length was 210 feet. Following these trials, Mr. Ely used the same plane on four wildfires with good effect noted by fire fighters on three of the four fires.(9)

In testing the efficiency of chemical fire retardents during 1956 the opportunity occurred to observe air drops made on 25 fires. Based upon reports received from field officers of the U. S. Forest Service and the California Division of Forestry, it was concluded that the drops had provided some degree of aid on 20 of the 25 fires.(9, 13) The air attacks on fires during the 1956 season were largely made possible through the efforts of Ely and the cooperation of six agricultural aircraft owners located at Willows, Corning and Red Bluff.

The operational procedures developed by the Mendocino National Forest for use of the air tanker squad by both National Forests and California Division of Forestry Ranger Units listed the going charge per flying hour as sixty dollars. When the planes were not flown more than one hour per day, the Mendocino Forest had arranged for stand-by payment of fifteen dollars per day. If the plane was to be held on standby at other than its home port, the rate could advance to 35 dollars per day.(18) These charges are interesting in light of later rates. In spite of rather widespread air attack activity during 1956 certain areas of doubt still remained at the end of that fire season. These were:

1. How much water and chemicals penetrate various cover types and cover densities?

2. What are the relative merits of various sizes and types of planes?

3. How can we best distribute or concentrate planes for initial attack?

4. How can we make the best tactical use of many planes on large fires?(9)

Further test drops were made at the Willows Airport in October of 1956. It was generally concluded at that time that the small drops of 200 gallons or less would not be effective when made from a height of more than one hundred feet above the vegetation. A cross-wind of more than ten miles per hour also would contribute to the possibility of missing the target. A gate area of less than 175 square inches or tank venting of less than one square inch per five square inches of gate opening both appeared to produce insufficient rate of discharge when the plane was flying at speeds of more than 110 miles per hour.

The use of air tankers on California forest fires during the 1957 season was four times greater than during 1956. During

1957 625,000 gallons of water and fire retardent mixtures were dropped on 101 fires.[14] Significantly, the use of retardents exceeded the use of plain water for the first time. The 500,000 gallons of retardent used was largely sodium-calcium borate marketed as "Firebrake" by the U. S. Borax and Chemical Company. It is to be also noted that in 1957 two new aircraft types, the two-engined PBY and the large four-engined C-82, made their appearance on the scene.

It became apparent from observation and analysis of aircraft use on several large fires that efficient use and control of these new tools was greatly dependent upon better air-to-air and ground-to-air communications and upon the development of an organization plan that would permit their integration with the fire suppression team.[19]

As the 1957 fire season progressed, and as field reports on air attack success or lack of it came into the State Forester's office, it was obvious that the most spectacular success invariably was recorded on the smaller fires. The seven fires of this nature were all attacked by planes within 35 minutes after first report. The air drops were declared to have been instrumental in gaining control over the fires. Successful air attack, however, was not necessarily limited to small fires. Success was also recorded when the planes were used on isolated trouble spots developing along the perimeters of the larger fires and also where delaying action was needed to gain time for ground crews. One instance was noted where the borate retardent successfully prevented rekindling for more than one hour after accurate drops had knocked down the head of the fire.[5]

A number of conclusions were developed in the 1957 California Division of Forestry analysis. Because of their importance to the 1958 experimental operation several will be quoted below as they appear in the 1957 report:[5]

"8. In those other cases where aerial attack occurred after the first 30 minutes or when fire exceeded 15 acres in size, drops ranged all the way from successful to complete failure - primarily dependent upon the degree of accuracy of the drops, and upon the amount of coordination with ground attack."

"10. The majority of initial attack operations (as defined for the purpose of this 1957 report) occurred as a result of intentional effort to provide such action. Unless an aerial tanker was on standby ready for immediate dispatch or in the air at time of request, there was little possibility of the plane reaching a fire before it had exceeded 15 acres in size . . . . action."

"11. Pilots need a more intensive and planned training program than they have received to date ________especially when being used on the larger fires."

"12. Information still needed:

a. We need to more fully determine the relative (underlining added) effectiveness of the various aircraft types available to the California Division of Forestry as aerial tankers:

(1) On initial attack
(2) On large fire control
(3) Effect of relative times imposed by warm-up, get-away, and travel, and in relation to load capacities.
(4) Manuevering characteristics
(5) Stability under varying wind conditions.

b. We need more data on the effect of a single fixed size drop from varying heights, and on differing vegetation - -- weather, slope, etc., remaining constant.

(1) This problem may be an academic question since a pilot will drop from as low a height as he feels is safe. However, if there are two aircraft orbiting over a large fire where there is more than one drop opportunity, and/or the two planes have different sized loads, it could determine the most advantageous drop location for both planes.

c. We still need to find the upper safety limits imposed on aerial tanker operation by wind velocities:

(1) The highest velocity indicated on any of the fires was 20 m.p.h. This was on the U. S. Forest Service Wilcox fire and drops were classified as being fully and partially effective when made from an approximate height of 75 feet.

(2) A 12 m.p.h. wind was recorded for the Red Mountain Bar fires. Here drops made from a height of 50 feet were classified as being fully effective -- extinguishing the small 1,000 square foot spot and knocking out the entire head and upper half of the 1½ acres spot."

"14. Based upon all information to date it would appear that aerial tankers can be quite successful on small fires and spots with, or without, immediate crew followup. Where travel time of ground crews is great, aerial action may be a decisive factor in holding a small fire until arrival of ground forces. . . . anticipated."

From the above excerpts from the 1957 Report it is obvious that some of the questions that followed the 1956 activity still persisted after the summer of 1957.

PLANNING FOR THE 1958 AIR OPERATION

As the 1957 fire season ended in Northern and Central California, the Division of Forestry activated the "Santana Task Force". This group of personnel and equipment was selected from the five other Districts within the Division and redistributed to key fire stations in Southern California. They thus reinforced the regular crews in District VI at a time when that area of the State is normally jeopardized by the strong, dry winds known as "Santa Anas" or Santanas".

The occasional success of the air tankers earlier in the summer led to the proposition that two Stearman and one TBM air tanker from Northern California be considered part of the "Santana Task Force". Aircraft Operators Robert Roberts of the Sonora Flying Service, Harold Hendrickson and Lee Sherwood offered to place their air tankers on constant standby at the Ramona Airport in San Diego County without any flight time guarantee by the State. This offer was indicative of the fine cooperation the fire protection agencies received from all the pioneers of the air tanker fleet. It also demonstrates the visionary confidence these pilots had in the ability of their planes and themselves to perform a real service in fire suppression.

The 1957 air attack analysis, quoted in part above, had already proceeded sufficiently to reveal those areas of uncertainty surrounding the efficient use of air tankers. After stating the problems encountered in a preliminary manuscript dated October 21, 1957, the Fire Research Section of the Division Fire Control office established the following objective:

"In view of the above stated problems, it shall be the objective of the experimental phase of the Santana aerial tanker operation to develop means for measuring the known factors, analyzing the measurements, evaluating the analysis, and arriving at recommendations for future use of aircraft on initial attack."

The basic plan consisted of utilizing the two stearman (or N3N's), the TBM and one light observation aircraft as an air initial attack team. The planes were to be dispatched singly and in various combinations in order to study comparative results. Time factors relating to loading, getaway and travel would be recorded, meteorological conditions would be determined, fuel conditions measured, and terrain noted. An air observer who was to accompany each attack in a separate light plane would note fire behavior (spotting, rate of spread and intensity) and the drop technique in respect to hits around the fire perimeter as well as general results obtained.

The scope and details of the study as thus outlined were considerably more optimistic than the occasion warranted, however. Exceptionally early rains occurred and ended the fire season shortly after the main task force arrived in Southern California. The air tanker squadron, although alerted, was not requested to move South for standby at the Ramona Airport. When the early rains cancelled further opportunity during 1957 to investigate the full potential of the initial attack concept, it was immediately decided to project the Santana air attack planning effort into the next summer. The Division's North Coast District also began preparing a proposal for an air initial attack operation to be conducted during 1958 in its area of responsibility. The District I draft was completed on January 13, 1958, and the statewide plans were initially released one week later on January 21.

The plans prepared in Sacramento then underwent three revisions in order to incorporate some of the concepts from the North Coast planning as well as other suggestions received from throughout the State. After careful screening by Chief Deputy State Forester John Callaghan and Fire Control Deputy Walter Winters, a proposal was finished and submitted to the Department of Finance on March 14, 1958.

This plan called for the establishment of three operational research projects. Each project was to be run on an initial attack basis providing for immediate dispatch of standby aerial tankers upon first report of a fire start. An aerial observer was to accompany each initial attack and make factual observations and measurements of the action, the fire behavior and related factors as encountered on each fire. It was hoped that the analysis and evaluation of the air attack would provide the information needed for guiding action on future initial attack operation as well as on large "campaign" fires.

Three project areas were selected on the basis of their record of large fire occurrence. Since financing the air operation was the largest single hurdle to overcome, the Division assumed from the beginning that criteria would have to be established which would discourage the dispatch of the planes except to those fires having the potential of reaching a large size if not quickly suppressed. To determine what the approximate initial attack action might be C, D, and E size fires occurring during the 1955 and 1956 seasons were plotted within a specific time radius of each proposed air base. To provide for even more freedom of decision by the Dispatcher, this figure was then doubled. To protect against over expenditure of limited initial attack funds, it was assumed that initial attack would not be charged beyond the first three-quarters of an hour. This would permit one drop being made on a fire occurring near the outer perimeter of the initial attack area, more if the fire was closer to the air base. The total number of anticipated dispatch actions during the life of each project multiplied by three-fourths hour per fire multiplied by the going rental rate for each particular aircraft type used, formed the basis for determining a budget estimate. The budget estimate made by the North Coast District was based upon detailed analyses of prior fires to determine to which fires the Dispatchers would probably have sent air tankers. Although the approach was different from that used in the State Forester's analysis, the budget estimate developed for air tanker use was only slightly under the ultimate fund allocation.

The North Coast project initially was to consist of two Stearman type Air Tankers at the Garberville strip in Southern Humboldt County, a Stearman and a Beechcraft AT-11 at Willits Airport in Mendocino County and two Stearman type at the Lakeport strip near Clear Lake in Lake County.

The third project area was to be in Southern California at the Ramona Airport. Here the Division proposed to place state-owned TBM or Beechcraft AT-11's (depending upon availability). By providing a fully controlled operation at this site, it was hoped to develop a cost comparison between state-owned planes and the contract air tankers being used at Sonora and on the North Coast.

The proposed budget as it appeared at this stage of program development was as follows:

Ramona:	
Acquisition, modification and operation of 1 TBM and 1 AT-11 plus rental of 1 Cessna 180	$50,650
Columbia:	
Rental of 1 TBM, 1 Stearman and 1 Cessna 180	22,795
North Coast:	
Rental of 5 Stearman and 1 AT-11 (Observation to be existing Air Patrol)	20,250
Total Plane Rental	93,695
Borate Fire Retardent	42,500
Total Program	$136,195

Although the Division was able to procure two TBM's declared surplus to the needs of the U. S. Forest Service, the Department of Finance felt that they were not in a position to authorize conversion and use of the TBM's without specific legislative sanction. They also requested that Forestry reduce the number of bases in the North Coast area to two with a complement of not more than four air tankers.

The proposed air tanker program as submitted on March 14 was therefore revised and resubmitted on May 27, 1958. This submission followed the recommendations accepted in joint conference between representatives of the Department of Finance, the Department of Natural Resources and the Division of Forestry. The scope of the program was defined and it was determined that the entire initial attack phase of the program had to be financed out of savings already realized within Forestry's operating budget and from additional sacrifices to be selected by the Division from its equipment budget and from delayed appointments to vacant budgeted employee positions.

The Director of Finance approved the scope of the Division's air initial attack proposal on June 19. The details involving contract stipulations, awarding of contracts, dispatch criteria, selection and training of personnel to act as observers and program coordinators in each operating area, and so forth, continued to be developed up to the time each operation was scheduled to commence.

On July 8, the State Forester requested that no project be activated until certain controls were established which would prevent the use of air tankers on those fires which were legal (range improvement burns, and similar permit fires being legally conducted). He expressed further concern regarding the wording of the contracts to be entered into between the State and the Air tanker operators. The need was emphasized for properly protecting the State, its officers and employees from liability if damages should such occur. The Chief Deputy clarified these areas of doubt to the State Forester's satisfaction that afternoon. Final written approval for activation of the program was issued by the State Forester before 5 p.m., of July 8. The first project scheduled for activation was that of District I. The fact that this date had been previously designated as July 15 emphasizes how time had become such a critical factor in the initiating of a program of this size. Needless to say, the eight-hour work day had long past been forfeited by all those responsible for the various phases of planning and conducting the program.

A general problem area to which considerable attention was devoted was the mixing of the borate retardent, transfer of the retardent to the planes and difficulties due to various tank and gate designs. Floyd Waklee, an Equipment Engineer on the Fire Control staff, had expended considerable effort since 1954 on design and improvement of such equipment. When sodium-calcium-borate slurry continued to show excellent possibilities as an air delivered fire retardent during the 1957 season, it became imperative that a fast, inexpensive method of producing a consistent mix be developed.

Robert St. John Orr, owner of the Western Fire Equipment Company, had earlier developed a prototype mixer which operated by feeding the borate powder from a hopper into a water stream moving at high velocity. Utilizing the venturi jet principal it then became a matter of trial and error to establish the proper water orifice/powder orifice ratio so as to produce a mix of about three and one-half pounds of borate per gallon of water.

Personnel of the Pacific Southwest Forest and Range Experiment Station worked closely with Division engineers and the Western Fire and Equipment Company in this development. A modified production model of the mixer that was initially developed in 1957 was finally produced in time to meet the July 15 deadline. Pumps salvaged from surplus water filtration plants which would effectively move the slightly abrasive borate slurry without undue wear or loss of efficiency were put to use. War surplus tanks of 10,000 gallon capacity were also located and shipped to the various points of use. Where water could not be obtained under adequate pressure (150 psi), Division pumps were diverted from other use and established at a water source in order to provide water to the mixer.

CONDUCT OF THE 1958 INITIAL ATTACK AIR PROGRAM

The program as it was ultimately developed throughout the State appears as follows:

Hoberg's Airport, Lake County

1 N3N owned and operated by George Jess (crashed on September 15 fatally injuring Pilot Jess)

1 Stearman owned by Lampson Air Service piloted by Thomas H. Oster

1 Cessna 182 owned and piloted by George Justman

Drop Coordinator and Project Leader for District I - George Berdan, Associate State Forest Ranger

Facilities:

1-10,000 gallon retardant storage tank

2-Transfer Pumps

1-Pressure Pump

1-Jet Mixer, Western Fire Equipment 12x400

1-Portable Office, 8 x 8

1-Portable transmitter - receiver radio

1-Sedan (crew transportation)

(Part of the facilities established at this Air Base are shown in Figure 1)

District I (North Coast)

Period of Activation: July 15 to September 30

Ukiah Airport, Mendocino County

1 N3N, owned and operated by Harold Hendrickson

1 N3N, owned and operated by Frank Prentice

1 Cessna 182, Pool's Air Service, combination

aerial patrol and air tanker observation - Pilot: Joe McCoy

Air Observer: Gene Glavich, Forest Firefighter Foreman

Facilities:

2-1500 gallon canvas tanks for borate retardent

1-Transfer pump for loading purposes

1-Jet Mixer, Western Fire Equipment, 12 x 400

1-Hi-pressure pump

1-Portable transmitter - Receiver Radio

Hanger space was utilized as a ready room (provided by Pool's Flying Service)

The instructions prepared by District I for the guidance of their field personnel also spell out the "Stand-by and Dispatching criteria" used in this project area. Since the general instructions are also indicative of the planning effort required by all Districts involved in the initial attack air program they are attached as Exhibit A.

District III (Central Sierra)

Period of Activation: July 28 - Oct. 15

Columbia Airport, Tuolumne County

1 TBM,[1] Contractor: Sonora Flying Service

Pilots: Robert Roberts and Mel Coeur

1 Stearman,[2] Contractor: Jensen's Flying Service

Pilot: Robert Waldron

1 Cessna 180, Contractor: Sonora Flying Service

Pilot: Mrs. Robert Waldron

Drop Coordinator and Project Leader: Edward Berger, Assistant State Forest Ranger

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[1] A second TBM operated by the Columbia Flying Service qualified for substitution when needed.

[2] This plane not used on fires after September 14, Contract terminated

Facilities:

2-10,000 gallon tanks (1 slurry, 1 water)

2-Transfer Pumps (1 furnished by contractor)

2-Jetmixers (1 contractor, 1 USFS)

1-Borate Storage Bldg.

1-Record Office

1-10 watt portable transmitter - receiver radio

1-Pickup (crew transportation)

(Refer to Figure 2 which shows the basic layout which was established at the north end of the Columbia Airstrip)

Standby was based upon the degree of fire hazard predicated for the day in question. Unlike the District I operation, the burning index used was the new California Burning Index:

Extreme (27-100) - 0800 to Sunset

Very High (18-26) - 1000 to Sunset

High (12-17) - 1200 to 1 hour before Sunset

Moderate (5-11) - Planes to be available on 15 minute notice

All dispatch was done through the Tuolumne County Ranger's Headquarters in Sonora. Each using Ranger Unit was responsible for initiating its own request as was done elsewhere throughout the State.

1. Planes would be dispatched to only those fires occurring within a 20 minute flight time radius of the Columbia Airport - approximately a 60 mile radius for the TBM.

2. Planes would not be dispatched on forest fires occurring within a 5-minute ground travel time from forest fire stations.

3. Planes would not be dispatched on those fires which from past experience, or upon reliable information indicated no large fire potential.

4. Planes would not be dispatched to fires in zone 2 (secondary watershed and timber lands) unless they occurred at a point more than 45 minutes ground travel time from the closest manned fire station.

5. If the burning index was moderate, there would be no dispatch to fires in zone 2 and then only to zone 1 fires starting in a high value area or where travel time for crews exceeded one hour.

There were no priority guidelines established in event of simultaneous request for the air tankers. If a situation such as this occurred involving two separate Ranger units, the District Dispatcher would make the decision as to which fire would receive air tanker priority.

District VI (Southern California)

Period of Activation: August 20 - December 1[1]

Ramona Airport, San Diego County

2 TBM's: Contractor - Frontier Airways[2]

Pilots: Ralph Ponti, Edward Rice and Clayton Curtis, owner

1 Cessna 180: Contractor - Frontier Airways

Pilot - Ronald Johnson

Drop Coordinator and Project Leader, James D. Taylor, Assistant State Forest Ranger

Relief Drop Coordinator: E. C. Carlson, Assistant State Forest Ranger

Photographer: Frank Williams, Forest Firefighter Foreman

Facilities:

2-10,000 gallon tanks

2-Transfer pumps (1-150 gpm, 1-250 gpm)

1-Pressure pump

1-Jet Mixer, WFE 12 x 400

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1 Extended to December 31 because of prolonged fire season and insufficient earlier attack opportunities.

2 A third TBM was transferred south from the Sequoia Field project on October 30 with no additional standby pay guaranteed.

1-Ready room and office (County building)

1-10 watt transmitter - Receiver radio

1-Pickup (crew transportation)

Tanks used at this air base were of two types as shown in Figure 3.

The Division of Forestry was required to negotiate a lease from the County of San Diego for the 6.92 acres used at the Ramona Airport. Arrangements were made with the Ramona Flying Service as prime lessor for lease of the space used as a ready room. A two-inch meter and pipeline had to also be installed so water could be purchased from the Ramona Mutual Water District. This was the only area in the State during 1958 where there was a monetary consideration involved in the establishment of air attack facilities.

All aircraft were to be ready for dispatch by 0830 PDT each morning. Due to the late start of the program in this area, it was determined that the only time the planes would not be placed on standby was when the weather appeared to almost exclude the possibility of a fire starting, or, when visibility was such at the Ramona airport that planes could not safely operate.

On those days that the squadron was activated, dispatch would be made on certain fires within a 50 mile radius of Ramona. (This radius was extended late in the season to include most of the State protected area within District VI).

The San Diego Unit Dispatcher who relayed all dispatch action to the airport utilized a specially prepared dispatch map for his guidance.

1. Critical watershed areas were delineated.

2. All areas not readily accessible to ground crews in zone 1 and 2 were delineated.

3. Areas excluded from attack action were:

   a. Residential area.

   b. Areas laced with power lines, etc.

   c. Areas of negligible fire control difficulty - orchards, pasture land, etc.

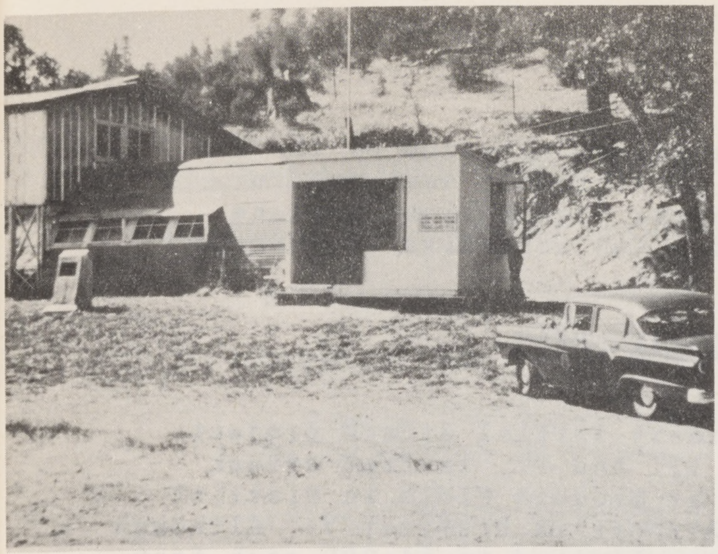

Figure 1
Portable Dispatch and Records Office - Hoberg Initial Attack Airbase - District I

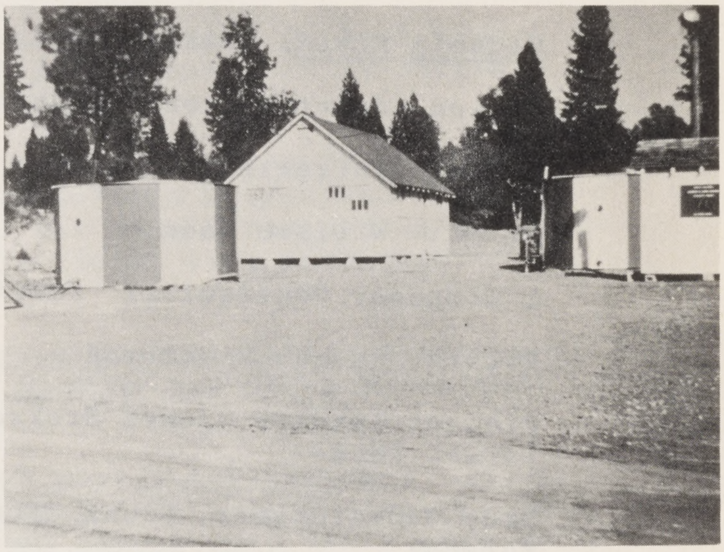

Figure 2
Fire Retardent Storage Building, Tanks and Time Keepers Office. Columbia Initial Attack Air Base - District III

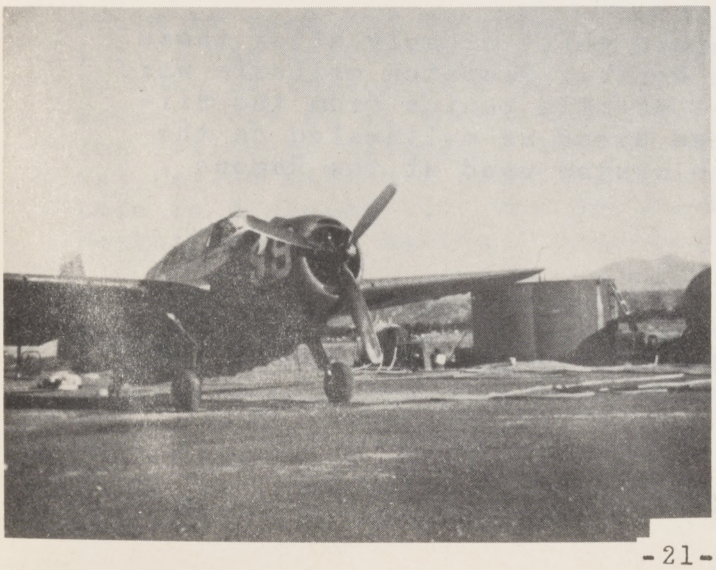

Figure 3
TBM Airtanker and two types of 10,000 gallon storage tanks Ramona Initial Attack Airbase District VI

Excellent photographic coverage was obtained of the air action in the project area. The photographer assigned to accompany the Drop Coordinator in the Observation Airplane had considerable skill and used his own expensive equipment.

SECONDARY OPERATING AREAS

In addition to the three primary initial attack project areas established in District I, III and VI, initial attack operations were also established at Sequoia Field in District IV and at the Salinas Municipal Airport in District V. Although funding of these two operations was limited to $4,000 each from the initial attack budget, both areas operated in a manner comparable to the three primary areas. While it was believed that additional information might be obtained from these two areas, their establishment was largely of an exploratory nature.

Sequoia Field, Tulare County

Period of Activation: August 15 to October 1.[1]

1 TBM, Contractor: Frontier Airways

Pilot: William Wood

1 Tripacer Contractor: Frontier Airways

Pilot: George Middleton

Project Leader: James Stokes, Associate State Forest Ranger

Drop Coordinator: Frank Troutman, Forest Firefighter Foreman

Base facilities somewhat duplicated the Hoberg Air Base with the exception of commercial water being available and also more adequate office space.

Standby criteria were patterned quite closely after those of the Columbia operation to the North. Dispatch criteria were based on fires occurring within a 60-mile radius from the airport and within certain prescribed areas as delineated on the dispatch map - somewhat after the system used at the Ramona operation in Southern California.

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[1] Extended to October 16 because of prolonged fire season and lack of earlier attack opportunities.

Salinas Airport, Monterey County

Period of Activation: September 13 to October 15

2 Stearman, Contractor: United Heckathorn

Pilots: Lou Ortali, Stewart Kunkee

1 Cessna 180 Observation - Tanker, Contractor: Hills Flying Service

Pilot: Harry Chaffee

Project Leader: Kenneth Harp, Assistant State Forest Ranger

Drop Coordinator: Larry Young, Foreman

Relief Coordinator: Carl Nova, Forest Fire Fighter Foreman

The facilities established at the Salinas Airport were similar to those at Ukiah. The Division was able to obtain good office quarters, however.

The standby and dispatch criteria did not differ greatly from those laid down for the Sequoia Field Operation. Due to the slower speed of the Stearman, the attack radius was lowered to forty miles and the permissable flight time increased to one-half hour.

Priority for dispatch was given to fires which might occur in the higher valued areas lying west of the Santa Clara and Salinas Valleys.

The largest variation in this particular operation was the double purpose served by the Cessna 180 airplane. The Division of Forestry had designed a small 60 gallon tank which when fully loaded with a borate slurry having a weight of 10.3 pounds per gallon would not exceed the load limit of the "180". The bid specifications called for the furnishing of a Cessna 180 with a tank patterned after this design. It was intended that the plane would be used for detection patrol on high fire risk days. When a fire was discovered the ship would be in an advantageous position to make an immediate attack with one drop prior to assuming its second role as an observation aircraft for the "Drop-Co" during the follow-up attack by the two Stearman Tankers. Figure 4 shows the Cessna making a practice drop during an early training session held in District V.. One of the Stearman supplied by United Heckathorn also making a practice drop appears in Figure 5.

The Safety Rules prepared by District V in consultation with Districts I, VI and the State Forester's staff are attached as Exhibit B. These rules with minor modification were used on the initial attack air operations throughout the State.

Figure 4
Cessna 180. Dual purpose air tanker and observation plane making low level drop - scaled height above vegetation is 11 feet.

Figure 5
Stearman making practice drop of 120 gallons at scaled height of 12 feet above ground surface.

DISTRICT II

Although $4,000 was allocated to District II of the Northern Sierra-Cascade area, the funds were not used to guarantee standby initial attack services. Since a large number of air tankers were already available and strategically placed throughout this portion of the State, the District felt that the money might be better spent for borate fire retardent material. It could then be properly charged against initial attack when such action could meet the initial attack definition. Even though planes were not intentionally placed on standby, owner-operators were occasionally in a position to respond immediately to a dispatch request. All dispatch action of air tankers in this area proceeded through the U. S. Forest Service Dispatcher at the Redding headquarters of the Shasta-Trinity National Forest. The majority of the report forms filed by personnel within the true initial attack project areas were also filed by State District II personnel. A comparison of some of the features representative of the two types of dispatch action thus became possible.

RELOAD FACILITIES

To augment the initial attack base ports, reload facilities were also established in all the initial attack operating areas. Travel time could thus be reduced on all runs subsequent to the first dispatch action when these alternate bases could be manned since they were in closer proximity to the fire than were the home ports. Small supplies of mixed fire retardent were normally on hand as well as drystock chemicals. In the event it appeared that travel times could be reduced by activation of a reload port, either the closest fire crew was moved in to mix and load, or local people who had been previously trained were hired on an emergency basis to provide this service.

CONTRACT SPECIFICATIONS

One of the most knotty problems encountered prior to and during the five initial attack operations revolved around the preparation and interpretation of the contract specifications. These specifications were drawn up to provide a sound, equitable, basis upon which the various interested aircraft operators could bid. Furthermore, the specifications had to meet the requirements of Sections 4, 5 and 6 of Division Circular Letter 110-2, dated July 22, 1958. This letter established the broad guidelines governing all air tanker use by the Division.

Section 4 of the above policy letter requires that the proficiency of the pilot and the airworthiness of the aircraft must be approved by the Chief Pilot of the U. S. Forest Service Region 5, or his representative. An alternative provided that approval could be granted by a staff member of the Division Fire Control Section if standards used were at least equal to those of the U. S. Forest Service.

Section 5 of Circular Letter 110-2 briefly describes the experimental initial attack program and indicates that all details surrounding each project must be worked out in advance.

Section 6 is quoted in full: "Aircraft used in the above-mentioned experimental initial attack operations will be used only under a contract which will include a clause saving the State harmless from liability incurred in the performance of the terms of the contract, and will include operational specifications approved by the State Forester setting forth the general conditions of use in an initial attack program."

As many of the operators as possible were contacted prior to the preparation of the specifications so as to prevent the inclusion of arbitrary requirements which might accidentally rule out some of the possible bidders. The minimum standards as specified by the Forest Service, or which had been set by the Division as a result of 1957 experience, were not lowered. Consequently, some potential bidders were not able to meet the specifications. Forestry was also able to predetermine the majority preference of possible bidders on how standby time should be computed, how to allow for flight time to and from home bases when the air attack base differed from the home base of the successful bidders, and when to commence accounting for flight time as opposed to time spent loading, fueling and taxiing.

One large factor which became apparent during the initial contacts was that the type of aircraft available for a particular operation was frequently dictated by the type of planes owned by the closest interested operator. The original planes which called for a Beechcraft AT-11 to be located at the Ukiah Base had to be cancelled because the Division could not locate an AT-11 operator willing to move into this area who could meet the specifications for this type of plane.

Because of the many provisions incorporated in the specifications, there is attached as Exhibit C a copy of the specifications as developed for the District III air initial attack project. Since one TBM, one Stearman and one observation type aircraft were used, this specification includes requirements typical of those used elsewhere in the State program.

REPORT FORM PREPARATION

Several report forms were designed for use by various personnel in collecting and recording information deemed to be important for final evaluation of air tanker action.

1. **Air Tanker Daily Check List and Operation Check:**

   This form provided for daily inspection and report upon return from each air attack operation by the pilot (s) and the California Division of Forestry Coordinator. It involves those activities related to each individual. Primarily inspections were made of the condition of the plane (s) for emergency use and the status of retardent supplies and equipment at the airport. (Exhibit D)

2. **Air Tanker Pilot and Observer Report**

   This form was initiated by the Coordinator or the individual receiving the dispatch instructions. Directions for location of fire were inserted and the cards then given to the Tanker Pilots and to the Pilot of the Observation aircraft. Information appearing on this form spells out the individual air tanker action and the opinions of both the air tanker pilot and the California Division of Forestry drop coordinator on the effectiveness of each drop and of the attack as a whole. (Exhibit E)

3. **Air Tanker Activity - Ground Crew Report**

   This form was filled out by the Fire Boss of each fire following initial attack action. Frequently, each crew Foreman (if more than one was on a fire) filled out a card reflecting his observations of the air attack action.

   Provision was made on this form for gathering certain basic weather information at the fire such as relative humidity and wind speed as well as slope and fuel type information. (Exhibit F)

4. **Air Attack Summary Report**

   This form was completed normally by the Drop Coordinator after Ground Crew reports had been forwarded to his operating base. It summarizes all initial attack action (ground and air) so a rather complete picture may be developed and judgment made as to effectiveness of air attack on a particular fire. (Exhibit G)

5. Fire and Air Attack Action Diagram

The project leaders in District III, V and VI provided diagrammatic maps of each fire indicating the location, direction and size of each drop made in respect to fire perimeter. These maps were extremely useful in later analyzing action which had been photographed with either still cameras or on 16 mm movie film. (see Figure 8 for example).

6. Photographic Records

The filmed action mentioned above served as a separate type of evaluation tool. Although not originally considered, it was included in final program formulation and guidelines were established in an effort to obtain consistent results among the various projects.

7. Loading and Time Keepers Report Form

This form was maintained by the Time Keeper assigned to each initial attack air base. It provided a check on the quantity of retardent material carried on each trip as well as the basis for flight payment. (Exhibit H)

8. Narrative Reports

Yet another means of evaluation was through the solicitation of narrative reports from personnel observing drop action. Frequently, the reports were presented in time sequence and so served as a check against the time recorded on other reports. Statements obtained from this source, while not consistent in format, often provided clarification of data collected elsewhere and not otherwise interpretable.

TRAINING

District I held three one-day training sessions at the commencement of the air program in that area. Key personnel from throughout the District attended as did all aircraft operators connected with the program, other agency cooperators and personnel from the State Forester's staff. In addition to the general information and instructions which were issued, each of the four air tankers made a series of practice drops at varying elevations above ground. The Forest and Range Experiment Station assisted in establishing a grid network of receptacles and measuring the amounts of retardent collected from each drop. Typical patterns were then reproduced for each of the air tankers, indicating concentration in gallons per 100 square feet. These drops provided the first opportunity for many of the Division personnel to watch an air tanker in action. They also gave the pilots needed experience in hitting an established target as well as helpful information as to what they could expect from their tank and gate designs.

A typical pattern developed by an N3N with a 300 square inch gate opening as opposed to patterns from the smaller load dropped by a Stearman through a 209 square inch opening is reproduced as Figure 6.

Somewhat similar indoctrination meetings were held in other Districts but without so large an attendance.

FUND ALLOCATIONS

As mentioned earlier the funding of the air initial attack program had to be financed from existing allocated appropriations. The total money available for redistribution to the air program amounted to $151,678. This sum was either initially allocated to the Districts for expenditures against the operating costs of the program or spent at the State Forester's level for initial stocks of borate, film, radios, etc.

The breakdown of these funds by District and purpose appears in Table 2.

INITIAL ATTACK DEFINITION

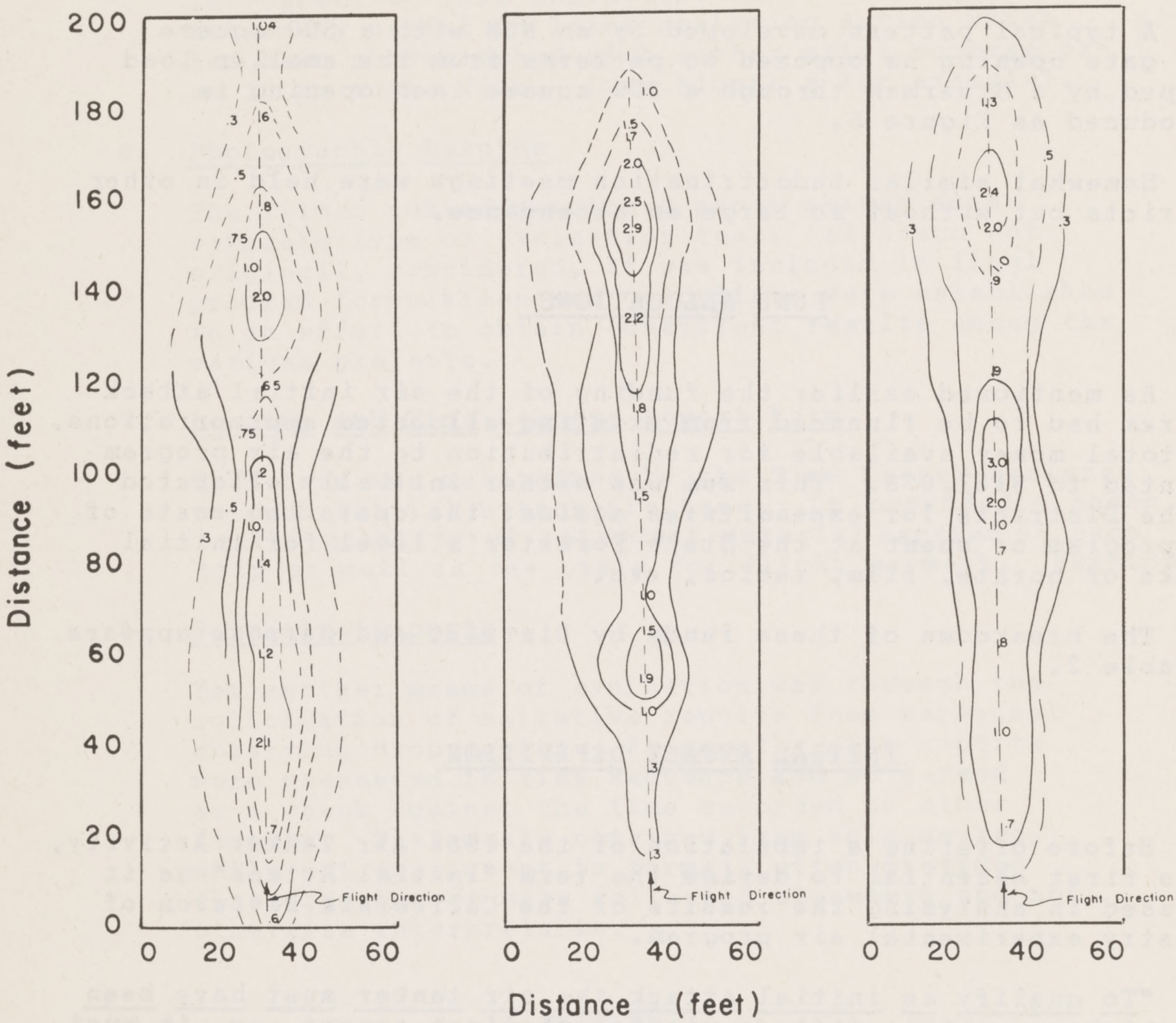
Before offering a tabulation of the 1958 Air Tanker Activity, it is first essential to define the term "Initial Attack" as it was used in analyzing the results of the California Division of Forestry experimental air program.

> "To qualify as initial attack the air tanker must have been airborne within fifteen minutes of first report, or, it must have arrived at the fire prior to the arrival of ground forces."

All other action not qualifying under the above definition is hereafter identified as "follow-up" action.(15)

EXPENDITURE CONTROL

A second area requiring clarification pertains to the time interval during which initial attack action may continue.



Ist. Drop 7/15/58	Ist. Drop 7/16/58	7th. Drop 7/17/58
Pilot: F. Prentice	Pilot: Tom Oster	Pilot: Tom Oster
Plane: N 3 N No. 21	Plane: Stearman 29	Plane: Stearman 29
Hgt. of Drop: 30 ft.	Hgt. of Drop: 20 ft.	Hgt. of Drop: 20 ft.
Plane Speed: 100 mph	Plane Speed: 80 mph	Plane Speed: 80 mph
Size of Drop: 180 gal.	Size of Drop: 120 gal.	Size of Drop: 125 gal.

Note: Contour lines represent coverage density in gallons per 100 square feet.

FIG. 6 DROP PATTERNS FROM HOBERG TEST OF JULY 15, 16 & 17, 1958

Table 2 Allocations for the 1958 Initial Attack Air Program

Area (District)	Aircraft Type and Number	Bid Rate ($/Hr.)	Guarantee Amount ($)	Operating Balance ($)	Borate Retardant ($)	Film ($)	Misc. Oper. Expense ($)	Radio Packsets ($)	Total District ($)
I	3 N3N's	$80.	12,000	4,640	7,109	201			
	1 Stearman	60.	3,000	1,000					
	1 Cessna 182	25.	2,500	275					
Sub Total I			17,500	5,915	7,109	201			30,725
II	-	-	-	-	4,000	-	-	-	-
Sub Total II	-	-	-	-	4,000	-	-	-	4,000
III	1 TBM	250	-	15,845	9,932	168	-	-	-
	1 Stearman	75	-	5,275	-	-	-	-	-
	1 Cessna 180	25	-	1,675	-	-	-	-	-
Sub Total III			-	22,795	9,932	168	-	-	32,895
IV	1 TBM	219		-	Stock transfer from III	-	-	-	-
	1 Tripacer	28	4,000	-		-	-	-	-
Sub Total IV			4,000	-	-	-	-	-	4,000
V	2 Stearman	54.6875	2,625	-	Stock transfer from III	-	-	-	-
	1 Cessna 180	27.50	1,375	-		-	-	-	-
Sub Total V			4,000	-	-	-	-	-	4,000
VI	2 TBM	219	27,000	14,235	15,985	298	2,595	-	-
	1 Cessna 180	28	2,250						
Sub Total VI			29,250	14,235	15,985	298	2,595	-	62,363
Total Statewide	16 (all types)	-	54,750	42,945	37,026	667	2,595	13,695	151,678

At some point in time it is commonly recognized that action may pass from the initial attack phase to what is frequently termed "campaign" or "large fire" status. With the limited funds provided for this experimental initial attack air operation, it became extremely important to establish this point of departure. Since initially those Division employees fiscally responsible for the expenditure of funds had no way of knowing for certain how fast the initial attack monies might be spent during the proposed period of activation, each project area established somewhat different criteria for terminating initial attack action. If the air tankers after that time were still required for further drops, subsequent action was charged to the "emergency fire suppression fund." This expenditure is then similar to the method of payment for contract bulldozers, chain saw rentals, pickup labor, etc., used by the Division after a fire has exceeded the immediate manpower and equipment resources of the Division.

Initial attack action might thus be terminated upon the basis of a stipulated number of drops, upon a preset time limit, upon reaching a specified fire acreage figure, or upon some combination of these factors. It might even be left to the complete discretion of the fire boss or the drop coordinator. In this latter event the decision to carry on further air attack under the designation of "campaign fire" action normally would be made when it becomes rather obvious that crews (and planes) either on the fire or enroute cannot suppress the fire without calling in reserve forces to assist. When such forces are C. D. F. crews from outside Ranger Units and a fire camp has to be established, or when private pick-up labor and equipment is used, this fact automatically places the fire in "campaign fire" status.

If air action qualifies as initial attack because it meets the dispatch or arrival time criteria but the fire then proceeds into campaign status insofar as funding is concerned, any drops made by the air tankers during both periods are carried on the records against "Initial Attack" for analysis purposes. Even though the fire is controlled fairly rapidly and without the use of outside forces or emergency funds, if the air attack does not qualify as "initial attack" because of our experimental criteria, drops are tabulated in the "follow-up" category. Payment for air tanker use in this latter event normally came out of the funds allottedfor the initial attack experiment. If air tanker action was extensive, however, some of the action was frequently charged to the emergency fire fund.

Admittedly the funding rules were fluid. The primary guide line was based on the need to extend the initial attack fund to the end of the proposed project period so money would be available to pay for the standby guarantee. When it became apparent in District I that the number of drops and time per fire was exceeding the original budget estimate, heavier use was made of the emergency fund. To control charges against the latter fund, the Deputy State Forester in charge of District I then established the rule that after three drops per plane had been made, further air action required approval of the District office. In the District III and District IV projects, one drop per ship was charged against Initial Attack. Further air action against the fire was then tightly controlled by District policy. This fact plus light fire activity consequently resulted in minimum initial attack and emergency fire fund expenditures. Due to the fact that the air attack projects began rather late in District IV, V, and VI, considerable action was charged against the Initial Attack fund. Even then neither District IV nor District V used up all the guarantee. It appeared for a while that the Ramona project also would not fully utilize the amount of the standby guarantee. While this explanation of the financial portion of the initial air attack program does not bear heavily upon the action analysis it does point up a critical area for future consideration, especially for agencies of government working under rigid budgetary controls.

THE 1958 SUMMARY OF AIR TANKER ACTION

To facilitate the review and analysis of the 1958 air tanker action considerable data was tabulated. Information was taken from the special report forms described above as well as from the Standard Fire Report Form, FC18, used throughout the Division for recording fire action and crew activity. Each fire receiving air tanker dispatch action was fully identified by name, number, date and location. The complete time sequence was established from time of estimated start to time of fourth drop in units of elapsed minutes. The average time interval between drops was determined for each fire. The first four drops had "gallons dropped" recorded and the total number of drops as well as total gallons dropped per fire were also tabulated.

In an effort to measure air tanker effectiveness with relation to the potential of each fire, the following steps were taken: The fire size at time of arrival was compared to elapsed time from estimated start; the burning index was examined as recorded at the fire weather station nearest the fire (or as taken from the ground report form); the type of vegetative cover (its density and height when estimated) was noted; the rate of spread and method of spread (spotting, crowning, etc.) and terrain factors were examined; crew action was studied in terms of the arrival times of the first three crews, in total man hours expended and in total "equipment use" hours. These data were related to the air action and to final control size.

Table 3, provides a tabulation of all State air tanker action which qualified under the definition of "initial attack" for the purpose of this analysis. Although the 28 tankers available in District II for dispatch on State fires were not on paid standby as part of the organized initial attack air program, dispatch of air tankers in District II which qualified as initial attack is shown in the Table for comparative purposes.

The dispatch of air tankers which did not qualify as initial attack is also tabulated and appears in Table 4.

All action by air tankers, both "initial attack" and "follow-up", on State fires as well as action by the Division of Forestry initial attack air tankers upon U. S. Forest Service fires is summarized in Table 5.

Table 3 Air Tanker Dispatch Actions on California Division of Forestry Fires Which Qualified As Initial Attack - 1958

Area (District)	Total Dispatch Actions	Results of Dispatch: False Alarms	Results of Dispatch: Controlled Before Arrival	Results of Dispatch: Actual Fires Attacked	Criteria for Initial Attack: 15 Minutes or Less Getaway	Criteria for Initial Attack: Arrival Before Ground Crew	Drop Record: Total Drops	Drop Record: Total Gallons
I	72	3	7	62	33	29	670	110,700
III	19	1	2	16	15	1	113	40,500
IV	4	0	0	4	2	2	14	6,050
V	6	0	2	4	3	1	28	2,760
VI	45	2	17	26	24	2	182	96,200
Total I. Attack Squadron Action	146	6	28	112	77	35	1,007	256,210
II (non-standby)	13	0	0	13	2	11	62	8,730
Total (All Action)	159	6	28	125	79	46	1,069	264,950

Table 4 Air Tanker Dispatch Actions on California Division of Forestry Fires Which Qualified as Followup Attack 1958

District Area	Total Dispatch Actions	Results of Dispatch: Controlled Before Arrival	Results of Dispatch: Actual Fires Attacked	Drop Record: Total Drops	Drop Record: Total Gallons
I	46	9	37	365	59,060
III	12	2	10	43	16,675
IV	4	-	4	11	3,525
V	7	3	4	21	1,960
VI	22	8	14	145	81,160
Total I. Attack Squadron Action	91	22	69	585	162,380
II (non-standby)	29	-	29	357	76,140

Table 5 Summary of All Air Tanker Action Reported by the California Division of Forestry During 1958

Type of Action	Total Actions	False Alarms	Results of Dispatch: Controlled Before Arrival	Results of Dispatch: Actual Fires Attacked	Drop Record: Total Drops	Drop Record: Total Gallons
I. Attack	159	6	28	125	1069	264,940
Followup	120	-	22	98	942	238,520
Misc. CDF[1] Fires	7	-	-	13	83	41,515
U.S.F.S.[2] Fires	13	-	-	7	31	15,800
Total	299	6	50	243	2125	560,775

[1] Action listed is by "pick-up" air tankers outside project (other than in District II), or on fires before initial attack program was established.

[2] Action by C.D.F. Initial Attack Air Tankers on U.S.F.S. fires upon request: 6 qualified as I.A., 7 as Followup.

EVALUATION

Analysis of the information collected during the 1958 air attack effort may proceed on both a subjective and an objective basis. Both methods have certain advantages and conclusions developed must necessarily lean on both techniques. Statistical treatment of some data frequently will provide support when that data is incorporated into a general subjective evaluation.

The first general review of the air action was based primarily on subjective analysis of each separate air attack. The data collected from the many report forms and sources mentioned above was extracted and tabulated in a convenient form so pertinent factors could be quickly compared for effect. Some 2,500 feet of movie film and more than 100 photographs in black and white and color were reviewed along with fire diagrams which showed drop placement in relation to the fire's perimeter. To provide substantiation of reported drop heights a full day was spent on film review by ten of the drop coordinators and Fire Control Rangers who participated in the Initial Attack Air Program. Each drop was reviewed, repeatedly if necessary, and notations were made by members of the group of the estimated height of plane at time of drop and also the time that was required for the drop material to reach the top of the vegetation.

The information thus collected was tabulated so averages could be determined and the degree of dispersion about each height and time average established. In addition to the drop action filmed on fires, seven drops made at the Hoberg Training Session were filmed and projected on the screen in "still" motion. The heights of the planes were established by projecting a known measurement (vertical tail surface, fuselage thickness, etc.) from the plane to the ground. The time required for the drops to reach the level surface of the landing strip was checked with stop watches and the three averages thus obtained are included in the following graph. (Figure 7)

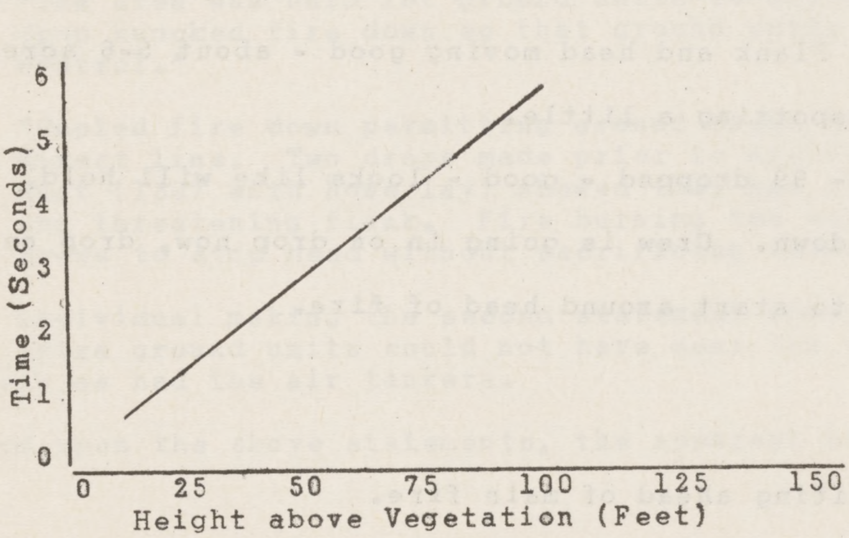


Figure 7
TIME REQUIRED FOR FREE FALL OF BORATE SLURRY TO REACH THE TOP OF VEGETATION FOR VARIOUS ESTIMATED HEIGHTS OF PLANE

The 82 fire drops and the seven test drops which were reviewed in the above manner and then graphed provide a useful guide for the future estimation of plane height when attacking fires. The film review also gave firm indication that a considerable amount of training of field personnel is needed before future height estimates may be relied upon. The standard deviation about the average height estimate (with estimates made by personnel most familiar with air attack) was in excess of one-third the estimated height for nearly every drop. This knowledge influenced the subjective analysis when an attempt was made to relate the reported data to the probable value of any particular air action. "Further measurements of height versus time are needed."

A sample of two analytical aids are included below. The first is a narrative report by the Drop Coordinator from the Ramona Air Attack Base. Included is a sketch indicating placement of drops.

The observer's recognition of spotting conditions[1] furthermore indicated that weather information appearing on the Fire Report Form FC-18 (taken from the nearest weather station--) (temperature: 69, Relative Humidity: 47, Fuel moisture: 16, Wind: SE 2 mph) was not apparently applicable to the fire site.

His estimate of the effectiveness of the air attack on this particular fire is supported by statements appearing on two reports submitted by firemen on the ground.

"12-6-58 - Cedar Fire - S. D. #345

Report Time 1246

1248 brush fire on Cuca Mesa (foot of Palomar Mtn.).

1304 on scene with TBM 99; will drop on N. W. Corner.

North Flank and head moving good - about 5-6 acres.

Head spotting a little.

1305 - 99 dropped - good - looks like will hold, fire laid down. Crew is going in on drop now, drop enables them to start around head of fire.

---

1 New fires igniting ahead of main fire.

1309 - TBM 99 dropping on N. Flank to connect Westward

with 99's drop, prevented flank (from) going around

first drop. Holding nicely.

1325 - TBM 97 dropped on flank; crew is progressing

slowly around head.

1330 - Crews are nearly around head - Will tie in other

flank with next three drops.

Did not hit head because of heat and a very poor run for TBM's to make. Planes were excellent on this fire, believe acreage would have been considerably higher without them.

S/ J. D. Taylor

Controlled at about 8 acres".

Ground Crew Statements

1. "The area was hard for ground units to get to. Air drop knocked fire down so that ground units could control."

2. "Cooled fire down permitting ground crews to work direct line. Two drops made prior to arrival of first unit (1307 with hose lay) showed they had slowed head and threatening flank. Fire burning too hot for ground crews to stop head without sacrificing acreage."

The individual making the second statement above felt that two or three extra ground units could not have done the same job as effectively as had the air tankers.

Based upon the above statements, the apparent burning conditions on the fire, the time of day, the number of initial attack crews hitting the fire and their arrival times, the rate of spread between time of report and time of attack and the apparent accuracy and noted heights of the drops, the air action on this fire was placed in the "materially aided" category.

The second analysis aid consists of a rather detailed fire diagram initially submitted by the Drop Coordinator of the Columbia Air operation. Added to the basic diagram is pertinent weather, terrain, fuel type and action sequence information. (Figure 8) Colored slides were then made of both the diagram and the actual fire site. These slides were shown on one screen while motion pictures taken of the drop action were shown on a second screen. This review coupled with the regular information obtained from the report cards and other sources led to placing the air action on this fire also in the "materially aided" class. Not all fires were so easily classified.

Of the 250 air actions by the initial attack squadrons, action on the 237 Division fires was examined subjectively. Seven broad categories were established within the two overall areas. "Initial attack" and "follow-up" as defined on page 29, above. Each action was then placed in one of the seven categories. These categories are as follows:

I - Completely successful.

II - Materially aided control efforts of ground forces.

III - Partially aided control efforts of ground forces.

IV - Of no aid to control efforts of ground forces.

V - Of indeterminate aid to the control efforts of the ground forces.

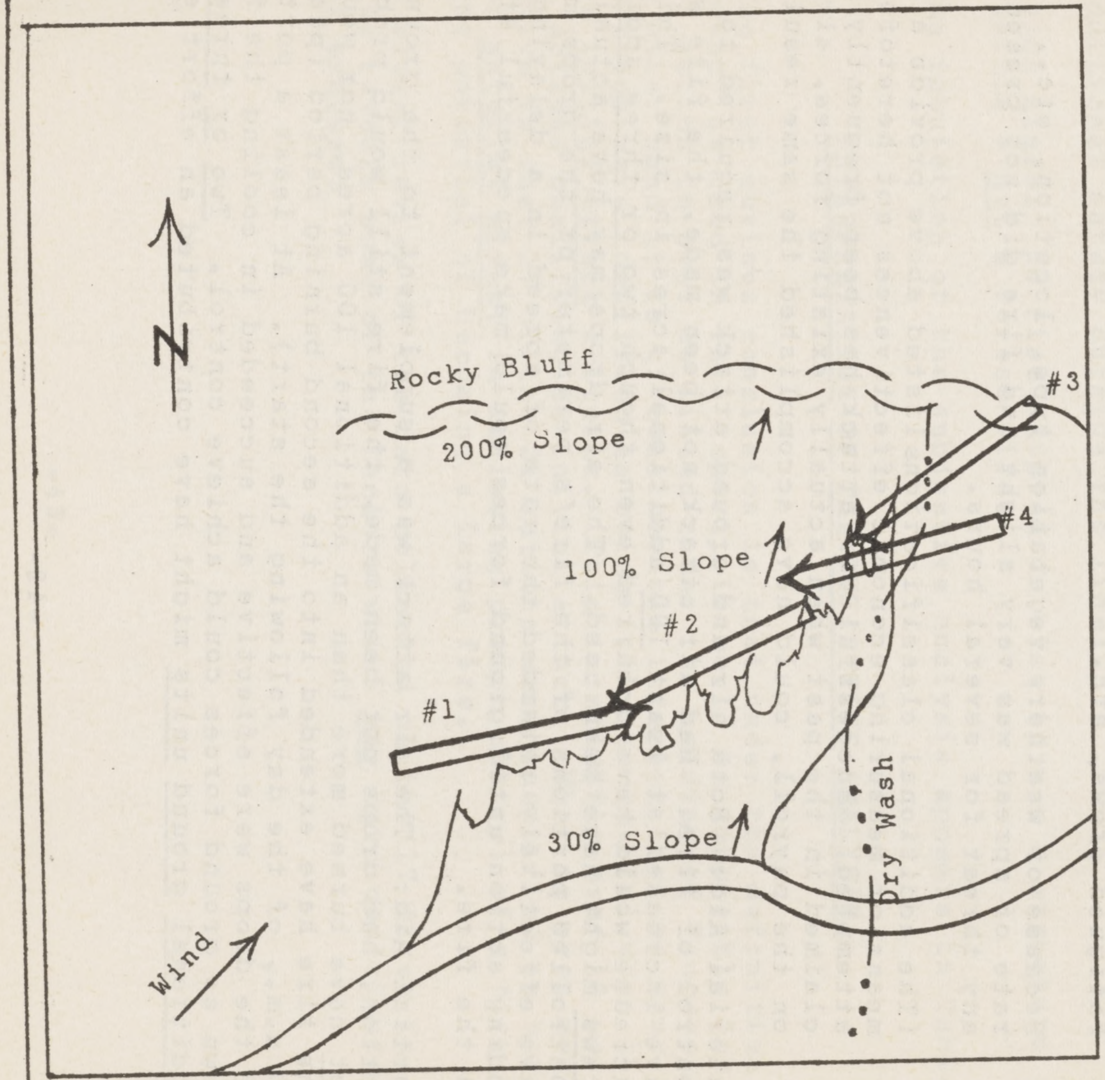
VI - Fire controlled by ground forces prior to arrival of air tankers.

VII - False Alarm.

The following types of action were placed in the various categories:

I. Fully successful:

Air tankers completely controlled the fire with little or no follow-up by ground forces required. The air tankers stopped the entire perimeter spread until ground forces arrived to mop up the fire. Since this classification does not indicate what the probability was for the fire becoming a large fire had there been



Camp Nine Fire

Calaveras County No. 157
Sept. 27, 1958
Sec. 15, T 3N, R 14E

Time: 1451

Weather: Temp: 90
R.Hum: 23
F.M.: 4.5
Wind: 4
B.I. (Grass) 13
(Brush) 10

Fuel Type: Chamise

Terrain: 30 to 200% Slope
inaccessible to equip.
for considerable distance
NE of bluff

Action: 1st Drop 1451
2nd " 1453
3rd " 1520 1st CR. 1522
4th " 1524 Bulldz. 1525

TBM--1/2 Loads

Figure 8 Sample of Fire Diagram and Related Data Used in Subjective Annalysis of Air Tanker Effectiveness no air attack, four sub-classifications were developed:

A. Had the ground forces initially dispatched been reinforced with at least two additional ground units at time of dispatch they would not have been able to control the fire at the same acreage achieved by air attack. (This assumes that such units would have been available had the decision for such dispatch been made.) The fire would probably have burned an additional 100 acres or more.

B. Ground forces enroute, or at fire but not yet taking action, would not have been able to halt fire at some acreage without the air attack. Extra loss would have exceeded 100 acres.

C. Had ground units been available for standard initial attack dispatch, they would have been able to halt the fire with but little trouble. (Normal dispatch action not taken because of action on other fires, fatigued crews, etc.)

D. Because of weather, vegetation type, location, etc., rate of spread was very slight and fire did not present any threat for several hours.

(The additional classifications listed above provide a means of measuring economic effectiveness not heretofore attempted. Successful air attack has been frequently claimed in the past when actually existing forces, already on the payroll, could have accomplished the same result.)

II. Material Aid: Both air and ground attack was required to enable control of fire. Had air attack not been made, the fire would have increased at least 100 additional acres in size. This increase would have occurred even though two or three additional crews might have been used. The air drops may have actually controlled portions of the fire's perimeter or the drops may have effectively retarded the rate of spread in a delaying or coding action until ground forces could make successful attack on the fire.

III. Partial Aid: The air attack was a supplement to the ground action; had drops not been made, the fire still would probably not have burned more than an additional 100 acres, nor would the fire have extended into the second burning period (past 10 a.m., of the day following the start). At least a portion of the drops were effective and succeeded in cooling the fire down so ground forces could achieve control. Two or three additional ground units might have contributed an effort equal to the air attack, had they been available.

IV. No Aid: Air action did not contribute to any earlier control of fire nor did it result in less acreage at time of final control. Fire may have been placed nearly under control by ground forces at time of air action; tankers could not make effective drops because of terrain, smoke, turbulence, wind, pilot error, etc.; even though well placed, had no beneficial effect on fire because of burning intensity and/or rate of spread.

V. Indeterminate Aid: Individual drops may have been well placed; sections of fire perimeter or entire fire may have been stopped but lack of prompt ground crew follow-up permitted fire to eventually rekindle and burn through or around the drops; spot fires developed which could not be controlled; drop action terminated because of darkness, etc.

VI. No Action: Fire was controlled by ground forces prior to arrival of air tankers - drops jettisoned or used purely for additional security on hot spots inside the line or to provide additional safety outside the line.

VII. False Alarm: No fire existed or else it was a structure or vehicle - not a forest fire.

The tabulation of the subjective analysis appears in Table 6.

INTERPRETATION OF THE SUBJECTIVE ANALYSIS

The first obvious conclusion is that under the definition of "follow-up" as used in this report, it would be impossible for that type of action to ever be listed under the heading of "successful". On the other hand it is of considerable interest that as many as 24 such actions were identified as being fully successful when they met the initial attack criteria. This is slightly over 16 percent of all actions qualifying as initial attack. What is even more impressive is that 17 of the 24 actions were identified as having been of material effect in achieving prompt control of a fire having a strong potential of becoming a large fire.

A closer review of the data collected on the 17 fires in question reveals some of the factors which may have contributed to full success:

Table 6

A Subjective Analysis of the Estimated Contributions of the Initial Attack Air Squadrons Towards Control of Forest Fires by District and Type of Action

Basic Action	District	Categories of Drop Action: I Successful A	I Successful B	I Successful C	I Successful D	II Material Aid	III Partial Aid	IV No Aid	V Aid Inde-Terminate	No Drop Action: VI Controlled Prior Arrival	VII False Alarm	Sub-Total
Initial Attack	I	2	12	4	2	10	19	7	6	7	3	72
	III	1	1	-	-	5	7	3	-	2	1	20
	IV	-	-	-	1	1	1	1	-	-	-	4
	V	-	1	-	-	-	2	1	-	2	1	6
	VI	-	-	-	-	2	18	6	-	17	2	45
Sub Totals		3	14	4	3	18	47	18	6	28	7	147
Follow-up	I	-	-	-	-	4	18	15	-	9	-	46
	III	-	-	-	-	1	2	6	-	2	-	11
	IV	-	-	-	-	-	2	2	-	-	-	4
	V	-	-	-	-	-	2	2	-	2	1	7
	VI	-	-	-	-	4	4	4	-	9	1	22
Sub Total		-	-	-	-	9	28	29	-	22	2	90
Total		3	14	4	3	27	75	47	6	50	9	237

Factor	Districts I	III	V
1. Height of the average of the lowest recorded drops	24 feet	75 feet	40 feet
2. Average get-away time	4 min.	3.5 min.	4 min.
3. Average travel time to fire	13.5 min.	8.5 min.	31 min.
4. Number of drops	7 @ 165 gal./drop	7 @ 300 gal./drop	7 @ 120 gal./drop
5. Time interval between drops	7.5 min.	20 min.	9 min.

The average listed above for District III and V were based on only two and one actions respectively and therefore are not very meaningful. From general observation of the overall action in Districts III and V, the data listed appear to be sufficiently different from action falling under other success classifications to warrant mention, however.

The question might well be raised as to why there were no actions identified as "fully successful" in the Ramona operation. Again, a review of the tabulation sheets show that out of the 45 air initial attacks which might possibly have been placed in the above category, only in ten instances did the air tankers arrive before the ground crews. While neither the get-away time nor the travel time were abnormally long in relation to the averages for similar action elsewhere (4 minutes and 15.5 minutes respectively), there were only a very few minutes lag before the arrival of ground crews on the fire in one-half of the above ten cases. Action then became a cooperative effort between the air attack and that of the regular suppression forces. In the other five cases one fire received only a partial drop because of mechanical problems; a 42 minute time lapse between the first and second series of drops on a second fire permitted effective control action to be started by ground crews which arrived about 30 minutes after the first drop; the drops on two fires were apparently high and ineffective. In the fifth case, even though dispatched while airborne and with a travel time of only ten minutes, total elapsed time between the estimated start of the fire and the first drop was 65 minutes. The fire had by this time reached a size of about seventy acres.

The relationship between air attack time - ground crew attack time is quite significant in overall comparison of air initial attack dispatch actions in District VI versus District I. In District VI, out of a total of 26 actual fire runs, only two qualified as initial attack because the planes reaches the fires first even though dispatch and get-away time exceeded fifteen minutes. Between the Hoberg and Ukiah squadrons of District I there were a total of 62 initial attack dispatch actions on actual fires. Twenty nine of this total qualified as initial attack even though dispatch time plus get-away time exceeded fifteen minutes. It is a well recorded fact that ground travel times in District I are long and this study further emphasizes this fact while also pointing up a possible economic solution.

Of those actions which were classified as having been of material aid in effecting control of a fire, twice the number appeared in the general category of initial attack as opposed to the number of actions listed in the broad grouping of follow-up actions.

As brought out in the introduction of this paper, there was a specific effort made to obtain some measurement of the economic value of air attack. This worth was not tied to dollar values but was related to another known factor - to the comparable ability of two or three regular crews to effect the same control action as achieved by the air attack. The estimated values of the air attack effort can thus be approximated by totaling the number of actions which were classified in the IA, IB, and II categories as defined on page 40 and shown in Table 6. There were a total of thirty four actions in these three groups (about three times as many in the initial attack as in the follow-up actions). If the estimate, usually made by experienced personnel on the scene, was reasonably accurate, provision would have to be made for at least two extra crews on the 34 fires. To pinpoint this comparison in the Northcoast project area this would require the use of 48 crews for the 24 fires having received material aid in that area. Since all 24 fires did not occur simultaneously, the establishment of a crew at a specific location would permit that crew to respond to more than one of the above fires. After plotting the 24 fires and selecting existing station locations which were closest to the fires involved, it appears that eleven stations equipped with two additional crews each might have provided the manning required to equal the effectiveness of the air attack. This approach makes the rather hazardous assumption that the crews could have reached the fire without undue delay. In practice were it decided to actually establish 22 additional crews in Lake, Napa, Sonoma and Mendocino counties, new one and two truck stations would be located on the basis of travel-time studies and fire incidence patterns. This could result in about 15 new stations located at approximately midway points from existing stations.

A word of caution should be introduced to prevent the development of an alternative conclusion -- the introduction of air attack does not necessarily mean that we could abandon 22 crews or 15 station locations and in so doing retain the current level of service. In no case was it found that the planes had completely extinguished the class IA and IB fires which they had successfully "knocked down". Mop-up action by "hand crews" was the only sure method of putting the fire out. In fact, in one recorded instance, a fire was discovered by the Drop Coordinator of the Hoberg squadron while he and the tankers were enroute to another fire. Drops were made as soon as verification was received from the Dispatcher that the fire was not a legal fire. Backed up by the two air tankers from Ukiah the fire was stopped at about four or five acres. The planes were returned to their bases as the ground crews approached the newly discovered fire area. However, the fire rekindled before firm control lines could be established and it burned another 75 acres and a house before being finally controlled. While continued action by the planes in coordination with the incoming crews may have prevented this loss, neither the planes alone nor the ground crew alone were sufficient. Furthermore, it must be pointed out that the planes cannot make night attacks nor can they replace crews needed for fire prevention, hazard reduction, telephone line and road construction and maintenance, or much of the other specialized work performed by fire control personnel. It presently appears that efficient dispatch of the air tankers will continue to depend upon good detection and precise pinpointing of fire location as well as the determination of "wildfire" status by ground forces.

STATISTICAL ANALYSIS

Many factors contribute to the manner in which any particular fire burns. Perhaps even more factors effect the control action which is brought to bear against any particular fire or the series of fires which contribute to the year's total. Fire Control agencies have not yet fully determined just how these various factors relate to each other. The California Burning Index perhaps comes close to measuring the intensity with which a fire may burn (and the difficulty of control). However, it is based mostly on several weather variables; it does not yet relate terrain nor the entire fuel complex to the overall problem of controlling a fire on a specific day at a particular location. Nor do we know precisely how action by various types of equipment or manning of a fire with various numbers and degrees of trained personnel may effect the control effort. In short, there is a decided lack of standards against which to measure any new technique such as the "air tanker". To further complicate the picture, there is a decided reluctance by fire administrators to permit their organization to become a "guinea pig" by alternating forces or equipment while trying out new techniques or equipment in an experiment which may take several years to conclude. The fire agency itself is subject to considerable public pressure. Should a large, disastrous fire occur which did not receive full action in the form of all the latest techniques available, a vast amount of explanation would be demanded by an irate public.

For the reasons above it becomes very difficult to establish a test design that can be adequately examined by convenient statistical techniques. Since this is the first season air action has been extensively employed, we have the results of only one test year to compare against the records established during previous years which might be considered control years. The records from this one year therefore do not represent a "population of data", and true statistical significance of any difference noted cannot be determined.

We can, however, examine the percentages of Class C fires, Class D and E fires and the full group of C, D and E fires controlled in test units and compare these percentages to similar percentages recorded in the prior years of 1951 through 1957 to see if there appears to be an improvement in control effort.

The geographical areas of prime interest to this analysis are those areas immediately served by the initial attack air squadrons. Furthermore, only those ranger units are being considered where use of the planes was sufficiently frequent and over a long enough period of time so there was the possibility of producing some impact upon the fire record.

The comparison of data appears in Table 7. Because of the fluctuating total number of fires year by year, data pertaining to the occurrence of the various size class fires has been reduced to percentages. The measurement of central tendency (standard deviation) is also expressed as a percentage of the fire class percentages.

Table 7 presents certain information which is worthy of more detailed examination. The records established in Mendocino, Sonoma, Napa, Lake and Calaveras counties all indicate a reduction in the number of the larger size class fires from the figure which might be normally anticipated. At first glance it might appear that the reduction has considerable meaning especially in Sonoma County where the number of 1958 D & E fires is one and one-quarter standard deviations below the 1951-1957 average number of such fires and in Calaveras where the decrease is one and one-third standard deviations. While the decrease in the number of D & E fires in Mendocino County is only about three-fourths of one standard deviation, this was accompanied by an even greater decrease in the Class C fires, so that in the three size classes a total reduction was made of over 2.5 standard deviations from the mean percentage. Although the reduction in the large size class fires (D & E) in both Lake and Napa is not quite as large, that reduction in both cases is still in excess of one standard deviation from the average.

A marked reduction in the number of Class C fires in 1955 and in the number of Class D & E fires in 1956 and 1957 combine to produce a noticeable downward trend in the total of all fires for the last three years of the 7-year study period in Lake County. The establishment of a trend line in this instance on the basis of 2.7 percent per year leads to the predicted total number of large fires as 24.4 percent rather than the 29.3 percent actually tabulated. The use of a trend rather than a 7-year average thus reverses the apparent success realized in Lake County during the 1958 fire season. While similar trends were not detectable in the other three counties, this fact introduces a note of caution in the statistical interpretation and emphasizes that factors other than air attack may effect the number of fires recorded year by year in the various size classes.

While the decrease in the D & E size class fires is quite consistent in the four North Coast counties, the same consistency was not achieved between the Calaveras and the Tuolumne units. There was in fact an increase in the number of D & E class fires in Tuolumne over the 7-year average. This latter increase occurred in spite of the fact that air tankers were based in about the center of the Tuolumne area of responsibility and were used on over 18 percent of all forest fires occurring in Tuolumne County during 1958. This compares to the use of air tankers on only about 10 percent of the forest fires in Calaveras County.

Table 7

Comparison of the 1951-57 Fire Record Averages to the 1958 Fire Records of Selected Ranger Units Participating in Air Program

	1951-57 Averages With Measure of Central Tendency								1958 Comparison to Prior 7 Year Averages						
Ranger Unit	Forest Fire Incidence	Standard Deviation	Percent of C Fires	Standard Deviation	Percent of D & E Fires (%)	Standard Deviation	Percent C, D & E Fires (%)	Standard Deviation	Forest Fire Incidence (%)	Percent of C Fires	Departure from Average in Stnd. Deviation	Percent of D&E Fires	Departure from Average in Stnd. Dev.	Percent of C, D & E Fires	Departure from Average in Stnd. Deviation
Lake	66.4	16.8	21.3	4.6	13.9	6.5	35.1	8.2	99	23.2	+ .19	6.1	-1.20	29.3	- .71
Men.	177.7	49.0	18.5	3.0	6.6	2.8	25.1	3.2	227	12.3	-2.06	4.4	- .79	16.7	-2.62
Napa	87.1	17.0	17.0	2.9	12.1	5.3	29.1	5.6	139	23.0	+2.07	6.0	-1.15	29.0	- .18
Son.	97.0	22.0	13.3	3.9	3.3	1.6	16.6	5.4	146	18.5	+1.33	1.3	-1.25	19.8	+ .59
Tuol.	41.4	7.1	14.7	5.0	7.4	4.4	22.1	7.4	60	10.0	- .94	10.0	+ .59	20.0	- .28
Cal.	84.3	19.3	16.7	5.5	7.4	3.3	24.1	5.9	131	14.5	- .40	3.1	-1.33	17.6	-1.10
S. D.	168.7	70.1	11.8	3.2	6.3	2.4	18.1	4.4	240	13.3	+ .47	6.2	- .04	19.5	+ .32

This inconsistency within a single area of operation will require further investigation.

When the favorable results above are related to the 1958 fire incidence, the reduction of the percentage of large fires becomes even more impressive. The number of fires experienced in Napa County during 1958 exceeded the prior 7-year mean by three standard deviations; both Sonoma and Lake counties experienced an increase in number of fires of two standard deviations over the mean, and Mendocino had an increase of one standard deviation over the mean. The relationship of decreasing numbers of D & E fires compared to an above average number of fire starts is graphed in Figure 9.

When a fire agency suffers such a general increase in fire activity it is normal to assume that available forces are spread more thinly to handle the increased work load; consequently the usual experience is that more fires escape early control and reach the larger size classes before final control is achieved.

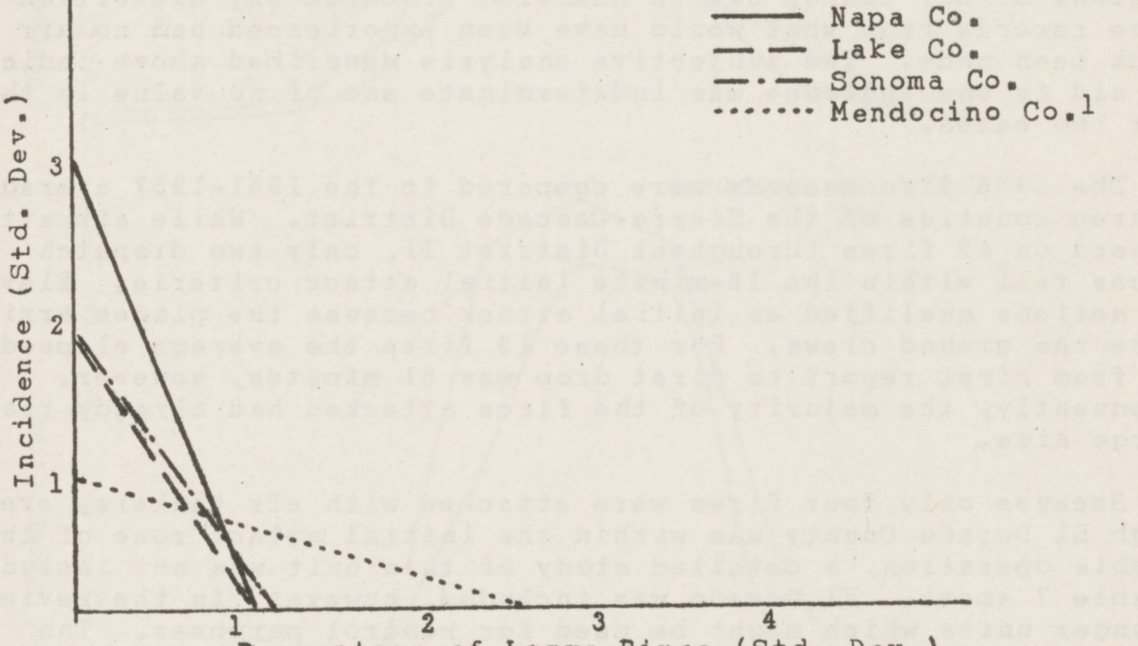


Figure. 9 Reduction in number of large fires in spite of increased fire incidence - a measure of apparent effectiveness.

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[1] Net decrease in C, D and E Fires

Before this assumption can be validly exercised, it is necessary to examine the attendant weather. If the fire weather record indicates that the actual severity is less than normal and that furthermore the burning potential has been spread over a larger base (longer fire season), the significance of the data graphed in Figure 9 is largely nullified.

Examination of the graphs reproduced in Figure 10, Page 53, does not indicate, however, that the fire season produced fewer number of fires during the peak incidence periods. In fact, it appears that the greatest increase of 1958 fires occurred during that period of time normally considered to be the peak of the fire season with an attendant smaller increase occurring both before and after the hottest part of the summer. The fire season began, as reflected by fire starts, slightly later than in the average year but extended to the date of average termination.

While the problems of introducing a control area into the experimental design has been discussed above, there are several ranger units which can be examined for general comparison. The Humboldt Unit is somewhat comparable in fire frequency, terrain and weather to the Mendocino Unit. It is doubtful that the three occasions of air tanker use in Humboldt produced any distortion in the records from what would have been experienced had no air attack been made. The subjective analysis described above indicated that aid in one instance was indeterminate and of no value in the other two cases.

The 1958 fire records were compared to the 1951-1957 averages in three counties of the Sierra-Cascade District. While air attack was used on 42 fires throughout District II, only two dispatch actions fell within the 15-minute initial attack criteria. Eleven more actions qualified as initial attack because the planes arrived before the ground crews. For these 13 fires the average elapsed time from first report to first drop was 81 minutes, however. Consequently, the majority of the fires attacked had already reached a large size.

Because only four fires were attacked with air tankers, even though El Dorado County was within the initial attack zone of the Columbia operation, a detailed study of this unit was not included in Table 7 above. El Dorado was included, however, in the review of ranger units which might be used for control purposes. The percentages of D & E fires was slightly lower than average and it should be noted that air action on two of the four air attack fires was classified as having been of material aid in effecting control. Since the average number of D & E fires was only 4.7, material aid on one or two fires having the potential of becoming large fires can be of importance in altering percentages.

Mariposa County was also within the initial attack radius of the Columbia operation but again the air tankers were used on only four fires. The one fire which received air action qualifying

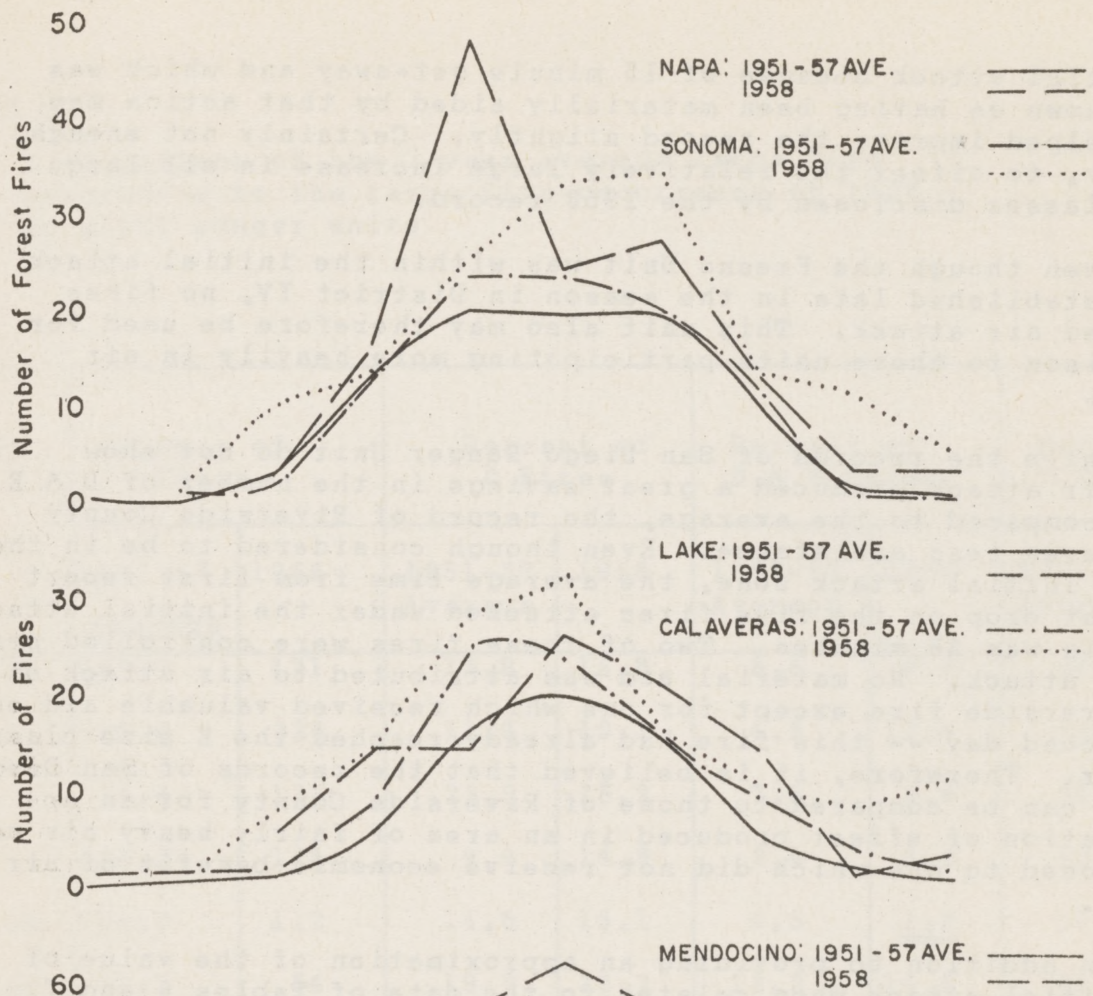

FIG. 10 FOREST FIRE ACTIVITY IN RELATION TO LENGTH OF SEASON IN SELECTED RANGER UNITS — ZONES I and II

as initial attack because of 15 minute get-away and which was also shown as having been materially aided by that action may have helped improve the record slightly. Certainly not enough, however, to offset the relatively large increase in all large fire classes disclosed by the 1958 record.

Even though the Fresno Unit was within the initial attack zone established late in the season in District IV, no fires received air attack. This unit also may therefore be used for comparison to those units participating more heavily in air attack.

While the records of San Diego Ranger Unit do not show that air attack produced a great savings in the number of D & E fires compared to the average, the record of Riverside County shows even less assistance. Even though considered to be in the Ramona initial attack zone, the average time from first report to first drop on the five fires attacked under the initial attack criteria was 38 minutes. Two of these fires were controlled prior to air attack. No material aid was attributed to air attaçk on any Riverside fire except for one which received valuable aid on the second day -- this fire had already reached the E size class, however. Therefore, it is believed that the records of San Diego County can be compared to those of Riverside County for an approximation of effect produced in an area of fairly heavy air use as opposed to one which did not receive economic benefit of air attack.

In addition to providing an approximation of the value of air initial attack when related to the data of Tables 6 and 7, Table 8 also substantiates the impression gained from Figure 10 that the 1958 fire season must be considered to have been more severe than the average year.

Table 8

A comparison of the 7-year average large fire occurrence to the large fire occurrence of 1958 in eight ranger units

Ranger Unit	Number of Fires		Percent of C Fires		Percent of D & E Fires		Percent of C,D,& E Fires	
	1951-57 Average	1958	1951-57 Average	1958	1951-57 Average	1958	1951-57 Average	1958
Humboldt	97.5	171	15.8	15.8	8.6	8.8	24.4	24.6
Shasta	149.0	229	11.9	10.1	4.2	11.4	16.1	17.5
Tehama	56.6	127	23.5	25.2	7.6	9.4	31.1	34.6
Butte	102.0	174	9.9	14.9	2.4	6.3	12.3	21.2
El Dorado	104.0	112	14.5	15.1	4.5	1.8	19.0	16.9
Mariposa	37.6	54	19.7	22.2	12.2	14.8	31.9	37.0
Fresno	36.0	59	15.5	23.8	8.3	8.5	23.8	32.3
Riverside	80.4	158	9.9	12.0	6.1	10.8	16.0	22.8

In summary of both the subjective and objective analysis described above and as condensed in Tables 6, 7 and 8, it appears that air initial attack in certain areas accomplished the basic objective of reducing large fire occurrence. The greatest consistent reductions in the number of D & E size class fires were in the four North Coast counties. Percentage wise, the subjective analysis indicates comparable degrees of success in relation to total number of attacks between the two areas of District I and District III. While the Ramona operation did not reveal a reduction in San Diego, comparison to the records of an adjacent county of lessor air tanker use indicates that large fire occurrence may have been higher had planes not been used in San Diego. The lower percentage of successful attacks in San Diego County as reflected in the subjective analysis apparently bears out the statistical records. The latter analysis gives indication why the reduction in large fire occurrence was not greater.

The statistical study did not indicate any reduction below the 7-year average number of size Class D & E fires in the three District II counties where air attack on a non-standby basis was rather heavily used.

GENERAL DISCUSSION OF THE 1958 INITIAL ATTACK AIR PROGRAM

Several requirements must be met before the potential values of air initial attack can be fully appraised. The period of use should be scheduled to coincide with that period of the fire season which normally produces the greatest number of large fires. While this period may vary from two and one-half months in the northern part of the State to perhaps six months in Southern California, results between various areas may be compared as long as the periods encompass similar degrees of large fire activity. Secondly, standby criteria should be comparable. If the Burning Index accurately measures the difficulty of fire control, a predicted index of 20 in one area of the State should mean the same as a similar prediction in some other area of the State. This perhaps can be verified by statistical analyses of large fire occurrence correlated with actual burning indices recorded for those days of such occurrence. If the present burning index is not comparable, adjustments should be made so the planes are all placed on standby when the large fire possibility is the same within the various experimental areas. This problem area was not thoroughly explored prior to the 1958 season. Dispatch criteria should also be designed so comparable dispatch action will be followed area by area. A basic object in making initial attack air dispatch should be to permit the air tankers to hit as many of the fires as safely possible which have the potential of reaching the C, D or E size classes if only normal attack procedures were followed. There may well be a variance here between areas which prohibits comparable action. The distribution of populations and accompanying power lines, telephone lines, etc., may limit air action in certain parts of the State even though fires starting in these areas have the potential of becoming large fires. While there were such areas excluded from air initial attack during the 1958 season, there was neither a study made of what percentage of total initial attack area was so excluded nor what past historical evidence may indicate in the way of large fire occurrence in these critical zones. It is believed that further study could develop this information and thereby differences between project areas may be taken into consideration. If only 75 percent of the initial attack area in one project can be reached safely by air tankers and if 10 percent of the past large fires have occurred in this excluded area, it is obvious that we should not expect the same degree of over-all success between this project and a similar project being conducted elsewhere in the State where perhaps 100 percent of the area can be reached by initial attack.

Not only should the base facilities be comparable in manning and equipment, but reload facilities within or adjacent to the perimeter of the initial attack area whould be comparable in number and location. Heavier use of reload bases in one project area than in another definitely provides a travel time advantage in the former case. The perimeter of the initial attack area should be based on a fixed travel time limit for the various plane types and these limits should be comparable between project areas. Areas based on distances alone do not permit ready comparison between aircraft types when their speeds differ appreciably.

Two large variables may be introduced into the fire control picture which is apt to seriously distort statistical comparison between years and/or areas. The first variable is that which arises when there is a change in personnel. This change may be the replacement of a Ranger or of one or more Assistant Rangers, or it may consist of changing the normal manning pattern. Both of these personnel factors were encountered during the analysis of the 1958 air operation. Ranger changes have been made during the last two or three years in all of the North Coast counties involved in that test area. There have been three Ranger changes made in Calaveras since 1951. Two new Rangers have administered Tuolumne County since 1952 with the latest appointment having been in 1957. In addition to changes in administration there have been several new 80-man conservation camps placed in operation in each of the test areas. Consequently, since 1951 there has been an increase in man-hours per fire of some 36 percent. This heavier manning with follow-up forces may have had an effect on the number of Class D & E fires. Certainly it must have helped to reduce the total acreage lost each year by reducing the average size of D & E fires. Since this analysis intentionally avoided consideration of acreage because only one fire can greatly distort acreage loss comparisons, the increased use of inmate crews may not have contributed much error to the analysis which considered numbers of fires in terms of percentages rather than acreage losses.

The second variable which may lead to faulty conclusions concerns the use of fire equipment. This factor not only relates to changes in administration and subsequent policies but also relates to improved design. In the past seven years, there has been increasing use made of four-wheel drive fire trucks. The Division has also added bulldozers to the fleet as well as supplemented the protection in certain areas by transfer of equipment.

The above factors primarily effect the validity of the statistical analysis. The subjective analysis is effected by personal bias and by opinion which may not be supported by sufficient experience. When the design for the 1958 operational experiment was developed it was hoped that there would be enough attack opportunities observed by a sufficiently large number of individuals so that bias and inexperience would cancel out in the overall analysis. The writer of this report has made a conscientious effort to remain unpredjudiced and it is believed that, if anything, a rather skeptical attitude has been maintained regarding the success of air attack. During the evaluation of reports the more conservative comments have been favored over those which were felt to be overly optimistic when the two were found to be somewhat in conflict.

One of the largest variables encountered in the entire program involved the differences in individual ability of the air tanker pilots. Certainly the most effective drops were more consistently made by those pilots who had had previous air tanker experience. An intensive two or three day fire control school is essential for proper indoctrination of the pilots. Not only must they be aware of the fundamentals of fire behavior, they must also know what to expect in the way of fire control action by ground personnel. Even then it is believed that more than one season's experience is necessary to produce a qualified air tanker pilot.

It is extremely difficult to separate pilot ability from aircraft limitation unless there are several similar air tanker types being employed in the same area. Where the operational design provided for this, it was rather apparent that certain pilots were not placing their drops as advantageously as were the other pilots. This difference was noted both in the North Coast operation where N3N's were employed and in Southern California where there were three TBM's ultimately working. The varying degrees of success noted between these two project areas might well be traced to this single factor of pilot ability. It is strongly suspected that if not the main factor, it contributed heavily to the general difference noted. While only one of the four small planes used in the District I operation was occasionally observed making ineffective drops, two out of the three TBM's had a number of poor drops recorded by field observers.

Yet another variable which must be given recognition concerns the physical condition and gate designs of the individual air tankers. There were very few equipment malfunctions reported in either the District I or District III air tanker operations. Both gate size and tank and gate design produced consistently good drop patterns. On the other hand, the aircraft used in the Southern California project had a number of mechanical failures which undoubtedly diminished their effectiveness. The TBM's had thirteen reported malfunctions. Seven of these failures involved the gate release mechanism. Oil line breaks and power plant difficulties accounted for the other mechanical problems. The observation plane suffered six reported incidents which caused delays or absences of the Drop Coordinator from his assigned role over the fire area. The tank design on these three TBM's also required improvement. A portion of the load was being trapped in a rear compartment and this produced a long, ineffective trail-out of an estimated 75 to 100 gallons of retardent. The tank opening should have no lips or edges exposed which would prevent free exit of the fire retardent liquid. The opening should be as large as possible so as to permit rapid release of the retardent. The length of the pattern can be controlled to a limited extent by varying the drop speed of the aircraft and the drop height. However, it appears that speeds in excess of about 130 to 140 miles per hour tend to produce excessive turbulence near the gate openings. Consequently, the fire retardent is broken up and disbursed as it leaves the tank. Whether any reaches the ground under such conditions again depends to a large extent on plane height at time of drop. Much more research is needed before we can precisely state the relationships between plane speed, height, gate opening and drop pattern.

Because successful air initial attack will frequently place the air tanker over a fire prior to arrival of the ground forces, the pilot must understand fire behavior. His "size-up" of the fire is just as important as it is to ground forces taking first action. If the fire is still but a spot, the drop site is obvious. If a head has developed, however, and the rate of spread is fairly fast, the pilot must make two estimates:

1. Will a drop across the head in view of burning intensity spotting and fuel type actually check the forward advance at this point?

2. If the estimate is that the head can be checked, will the rest of the perimeter continue to spread at a rate which will flank the original head before the air tanker(s) can return for a second drop series, or, before ground units can take advantage of the first drop? (Unless refill bases have been established, the time required to make the second drops will be a little over twice the time required for the first run).

Many of the techniques employed by regular suppression forces still apply as guidelines for air attack. If the head cannot be stopped because of burning intensity or spotting conditions, a flank attack which ties to some established control may well be the best action. Drops made just on the lee crest of a ridge will stand a better chance of checking a fire than would those made on the face of the slope immediately in advance of the flames. Drops made in light fuel naturally have a better chance of stopping a fire than if made in heavier vegetation. If there is a choice between the latter two fuel types, the drops should be made far enough in advance of the heavy fuel to contain any spot fires which might develop as the heavy fuel burns out.

If two or three drops are possible in fast sequence, one drop made directly on the head with the other drops laid just ahead of but slightly overlapping the first drop will frequently cool a hot fire that is threatening to spot.

It is the writer's opinion that a number of small drops (180-200 gallons) made from a low altitude (40-50 feet) above the fire, accurately placed and in fast sequence, is more valuable than an equal amount of retardent dropped as a larger single drop. The latter drop normally must be made at a higher speed and at a higher distance above the ground. Consequently, there is a natural loss of accuracy. Furthermore, if there has been a miscalculation and the drop misses its target the entire quantity is wasted. One of the three smaller drops could be mislaid and there would still remain two chances to make effective drops. The larger drops are best made when the drop site is somewhat level and the approach and departure zones are unobstructed.

The TBM's used during the 1958 operation all had two compartments and the gates could be opened in sequence thus producing a "train" effect. Drops made in this manner were very effective when the terrain was favorable and a long length of fire had to be checked. Nearly six hundred feet of fire could be held with one pass providing the pilot took pains to overlap his first and second drops.

Care had to be exercised on occasion to prevent drops from being made too close to the ground. When such drops are attempted directly on the fire line, rather than in advance of the fire, there is a tendency to scatter fire with the propeller blast as the plane pulls up. This may be more true of the larger horsepowered TBM than of the smaller types. The effect has been noted in both cases, however.

The types and numbers of planes used on initial attack as well as the distribution of airports caused two variations between operating areas to be especially noted. The average height of the lowest drops recorded per fire and the average time interval recorded between the first four drops are shown in Table 9.

TABLE 9

DROP HEIGHTS AND TIME INTERVALS BETWEEN DROPS BY PROJECT AREA

Area	Average Height of Drop (Feet)	Average Time Between 1st 4 Drops (minutes)
District I	32	8.5
District II	86[1]	17.5
District III	85	10.0
District VI	112[2]	16.0

[1] No drops were reviewed on film.

[2] This is a corrected average based on film review (50% added to pilot's estimate of height).

There have been a number of opinions expressed as to the maneuverability of the various types of aircraft used as air-tankers. When opportunities arose to observe both the small planes and the larger TBM's making drops in the same locations under terrain limitations, the small planes invariably made the better drops. This has been substantiated by various observers in District II, and by the Drop Coordinators of both the District III and the District VI operations. The N3N with a 600 horse-power engine had a decided edge over all other types in ability to climb steeply out of box canyons after making low drops. The Stearman with a 450 horsepower engine appears to be under-powered but it can still fly in tight situations better than can the TBM's.

The earlier estimate of the top wind speed of 10 m.p.h. which would prohibit accurate drops should be revised upward. Although no wind meters were used as verification, there were drops made which were recorded as accurate and effective when the estimated wind speed was about twenty-five miles per hour. Heavy slurry, low drop height, large gates and pilot ability all contribute to better drops during windy weather. Other factors being equal, it is assumed that the larger TBM drops would be rated more effective than smaller drops. This needs further verification, however. A serious attempt should be made to measure the several weather factors during the actual drop action.

A discussion of the relative merits of the various aircraft type used during the 1958 program would not be complete without a review of comparative operating costs.

A transportation efficiency curve developed for the N3N is graphed in Figure 11. This curve relates hours per gallon per mile against variable distances. By applying any given hourly rate this curve can be used to determine cost per gallon per mile.

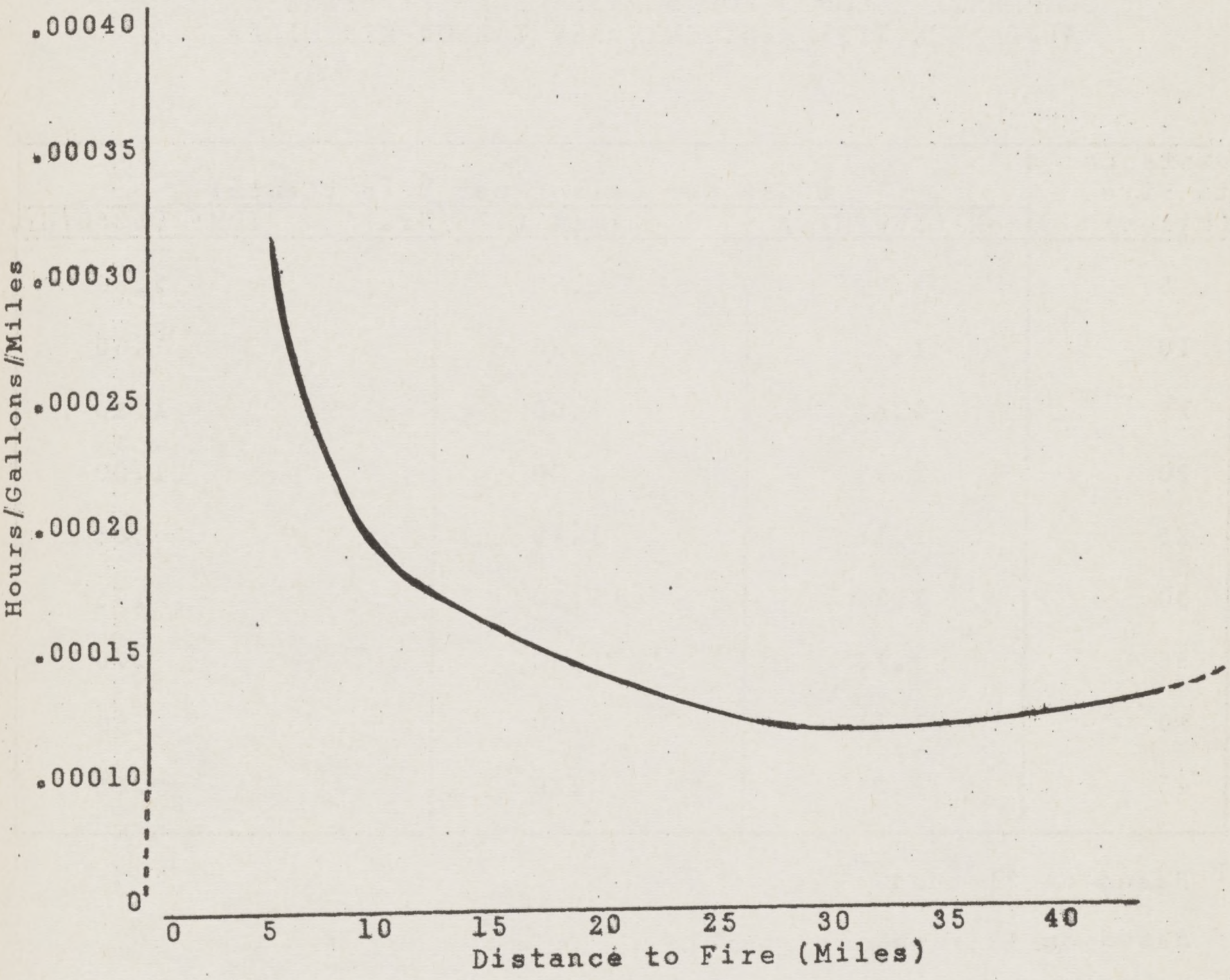

Figure 11. Transportation efficiency of N3N airtankers based on total drops made on 109 flights.

Table 10 provides a comparison of costs per gallon per mile based on a TBM rental rate of $250 per hour, a Stearman rate of $75 per hour and an N3N rate at $80 per hour. The data for the Stearman and TBM costs was derived from tabulated information compiled from all Stearman and TBM action in District III. That information was graphed in direct terms of cost rather than time, however. It does not represent as large a sample as the base used for development of the N3N cost efficiency curve.

TABLE 10

COMPARATIVE COSTS FOR BORATE DELIVERY BETWEEN AIRTANKER TYPES IN CENTS PER GALLON PER MILE

Distance to Fire (Miles)	(Cost per Gallon per Mile (Cents)		
	N3N ($80/Hr.)	Stearman ($75/Hr.)[1]	TBM[2] ($250/Hr.
5	2.72	2.50	2.60
10	1.72	2.20	1.60
15	1.42	2.00	1.20
20	1.29	1.70	1.00
25	1.16	1.40	.85
30	1.12	1.20	.75
35	1.13	1.00	.70
40	1.15	.80	.60
45	1.24	.70	.55

1 Based on 21 runs.

2 Based on 47 runs.

It is thus apparent that the larger payload and the faster speed of the TBM can put a gallon of fire retardant on the fire line at a cheaper cost (except for distances under five miles) than either of the other two types at the prevailing rental rates.

This cost advantage, however, must be closely weighed against effectiveness. Attention is invited to the apparent higher degree of effective action by the N3N's as shown in Tables 6 and 7, above.

After initial attack has been undertaken by the airtankers and ground forces begin appearing on the scene, the need for coordination between the two groups becomes urgent.

Communication must, of course, be established. Even though 24 special one-watt packsets were provided to help the air tankers and observation aircraft remain in contact with the crews, there were many times when communication failed. Some of the failures were due to the sets themselves. More frequently it was a case of parties not attempting to contact each other, not knowing (until too late) that others were also going to be on the fire, or of not being able to obtain air wave space. An air net with specially assigned frequencies is most desirable. The Dispatcher must also keep both air and ground units each advised of the other's estimated time of arrival or presence on the fire. More radio packsets should be provided to field units so that when they are advised that air tankers are coming in on the fire the crew can keep a radio with them, especially should they have to leave their truck. Beacon signals were devised by the Columbia Air Attack Observer to replace radio in forwarding directions to the air tanker pilots when radio failed. Some similar technique may be worked out which can be used to alert the ground units to the fact that attempts are being made to contact them by radio.

Coupled with this need for coordination is the problem of analyzing all the facts obtainable concerning a fire. Just as the Fire Boss of several years ago used an air scout as his eyes whenever possible he should now use the lead tanker pilot, or drop coordinator if one is present. Once the action gets heavy and the fire problem builds, many fire bosses like to take to the air in a helicopter or light plane themselves. They may then decide to direct both the air drops as well as the ground action. There has been ample evidence during the 1958 season that the individual in the grandstand seat about 800 or 1,000 feet above the fire is in an excellent command position.

The Division did not encounter any C. D. F. fire during the 1958 season which required the full air organization developed for air attack by the California Air Attack Executive Committee.(2) This problem becomes especially acute when large numbers of planes commence working the same fire and all planes are not using the same radio frequency.

Mention should be made of a side issue in the basic program. The California Forest and Range Experiment Station extended a considerable amount of effort in testing the fire retardent qualities of finely ground Bentonite Clay. This clay, when mixed with water in the ratio of about one pound per gallon, showed excellent possibilities as a substitute for Sodium Calcium Borate. Field tests were made on both District I and District III fires. The field use substantiated laboratory tests and it appears that this material will be a cheap, effective fire retardent for use with the air tankers.

CONCLUSIONS AND RECOMMENDATIONS

1. Initial attack with air tankers appears to be economically feasible. The N3N Tanker provided the highest percentage of fully successful attacks. This fact may have resulted from the presence of pilots more experienced in low altitude flying. On the other hand there is an indication that it is a better all around plane when used in sufficient numbers and when difficult terrain problems exist.

2. The TBM Tanker can deliver retardent to a fire at a lower cost than can other aircraft types tested. When the terrain is suitable and the fire is burning with considerable intensity, the TBM type tanker may produce a higher number of effective drops.

3. Main air bases and refill ports should be located so that the initial travel time to critical areas does not exceed fifteen minutes. Dispatch plus get-away time should be limited to five minutes. Sufficient planes should be used so the frequency of drops does not exceed six minutes for the N3N type or 10 minutes for the TBM type tanker under average burning conditions.

4. The effect of Burning Index on large fire occurrence must be closely examined. Another "build up" factor may have to be introduced into the Index to allow for a sequence of days during which time the index remains high. An arbitrary figure must be then decided on which will call for standby - perhaps if there is a ten percent chance of a D or E fire occurring at a given index this would warrant activation of the initial attack air squadron.

5. A study should be introduced to determine how many large fires occur at various attack travel times from ground stations. The elimination of air dispatch on fires occurring within five minutes of a manned station was an arbitrary figure. There was insufficient opportunity to test this dispatch criteria for acceptability. Once dispatch criteria is firmed up it should be uniformly applied.

6. Other factors such as terrain and fuel condition also contribute to large fire occurrences. These factors should be studied county by county to examine their possible effects on past large fire occurrence. This information should then be worked into the Dispatch criteria.

7. The airport facilities used at the various initial attack air bases were satisfactory for a one year experimental effort. The Division should attempt to develop permanent facilities based on the 15-minute travel time requirement wherever feasible and as correlated with large fire incidence studies.

8. Other factors than the experimental use of air tankers on initial attack contributed to the fire records established during the 1958 season. Continued observation and analysis of air initial attack will be required before significant results can be obtained. These other factors such as personnel deployment and equipment use should be held as constant as possible to prevent the introduction of additional variables into the basic design. Further consideration should be given to establishing one Ranger Unit as a control unit against which to measure various fire control techniques including the air tanker program.

9. Continued research should be devoted to the relative influences of air speed, wind, gate design, tank capacity and height of plane on drop pattern. Flame height provides an indication of the fires intensity and this factor should be related by fuel type to the size of drop which can be expected to cool a particular fire.

10. The airport and aircraft inspection report form should be continued in use after slight modification, and inspection schedules should be intensified when there is evidence of mechanical malfunctions. The other report forms used for analysis purposes will also require slight modification to clarify the information requested.

11. Training of both air tanker pilots in fire control techniques and of field personnel in how best to work in conjunction with aircraft will be a continuing requirement. The movie film used for analysis purposes is also an excellent training aid and should be exploited more heavily for both purposes.

12. The Division of Forestry should explore further use of Bentonite as a replacement for the more expensive borate. It appears that a Rhodamine-B dye will have to be used with the slurry so the drop pattern will be more visible to the tanker pilots and the air observer.

13. The fact that the Division had one contract terminated by the Contractor before the test period had ended points up a problem which must eventually be resolved. If air tankers are going to become an integral part of the Division's initial attack team, adequate performance must be guaranteed. Either the contracts must be tightened up or the Division should plan to obtain and operate an initial attack air squadron in the same manner it does fire trucks and bulldozers.

<u>Aerial Tanker Initial Attack Program</u>
<u>1958 Fire Season</u>
<u>District I</u>

I. Preamble.

During the past two years aerial tankers have been used on CDF fires in District I on several occasions. In most instances they dropped plain water. The effectiveness varied depending upon burning conditions, but the efficiency of the planes was most seriously impaired by the relatively long attack time from the time the fire started until the planes arrived due to their having to be dispatched from the Willows area. On some occasions planes were not avilable. During the course of one operation when the planes were working out of the Willits airport, another fire started and was attacked by the planes that happened to be at Willits. This incident demonstrated the effectiveness of initial attack by tankers.

In January of 1958, District I proposed a preliminary plan for the establishment of 6 aerial tankers in 3 groups of 2 each for initial attack action. This proposal received review at the State Forester's level and at the Department of Finance and it was not until June 23 that we received definite advice that a modified program had been approved by the Department of Finance. Briefly, the modified program consists of the establishment of 4 planes, 2 each at 2 locations, as bases.

II. Aim.

The objective of the program is to provide and evaluate the results of initial attack by small aerial tankers working under a planned operation in conjunction with established ground initial attack forces.

III. Evaluation.

Because of the fact that this is a new program it is most important that there be a thorough evaluation of it. In order to accomplish this it is planned that one man will be relieved of his normally assigned duties during the period of operation and will act as general project leader and will head up the program in its entirety including the evaluation phase. The evaluation, briefly, will be in two parts: one, the obtaining of facts, and the second the obtaining, as possible, of 16 mm moving pictures of the operation. In connection with the obtaining of facts, reporting forms will be developed which will be adaptable to IBM machine analysis. The project leader will be responsible for the collection of these reports and the completion of a final report including narrative statements of conclusions and observation for submittal to the State Forester's office no later than October 20, 1958.

The State Forester's staff will make the arrangements for rental of movie camera equipment and the project leader will obtain as much footage as possible commensurate with his other work.

Liaison will be maintained by the project leader, Sacramento staff personnel and District I field personnel in connection with the evaluation program to insure that it is progressing smoothly.

IV. Physical Aspects of the Program.

The following budget items are being allotted to District I for the 1958 operation.

Rental of aerial tanker planes for <u>initial attack</u>	$20,640.00
Rental of coordination plane	2,775.00
Film processing	201.00
	$23,616.00

In addition, from unallotted 1957-58 fiscal year monies, 68 tons of Borate have been ordered for assignment to the District I program. Also on order are 5-watt transistor radios for use in the tankers (refer to comments under "Communications" below). In our 1958-59 P & E budget are 5 Borate mixing units. These are being made up by Western Fire. Storage tank facilities have been obtained.

V. Operations.

A. Initial Attack Principles.

The 4 planes will be on standby basis at Hoberg's and Ukiah during the hours of 1030 (PDT) to one hour before sunset during the period of July 15 to approximately September 30 on days that the Hanna Mendocino index is 31 or more, or until the allotted funds for the initial attack phase are exhausted. The dates are subject to, first, availability of equipment and planes, and the final date is subject to weather conditions. The planes will have been warmed up prior to 1030 and loaded to capacity with gasoline. Because of mechanical problems, they will not be loaded with Borate but this can be accomplished without undue loss of time after receipt of a fire call.

Based upon weather records for the past three years, it can be expected that some 53 days will have a risk figure of 31 or more. On those days when it is less than 31, the planes will be released from their standby status and will be free to return to their home bases for other work. They will be available for recall back to standby status to be there no later than 1030 when the risk reaches 31.

Initial attack on the western and southern portion of the Mendocino National Forest will be included in this program, as well as the southwestern portion of the Six Rivers. Normally, use of the planes shall be limited to Zone 1 and 2 forest fires which are: 1) outside 30 minute ground travel time from an activated station; 2) occur during the period that the planes are on standby (as opposed to fires occurring at night; 3) are not small roadside fires with no potential.

B. Definition of Initial Attack.

Because of fiscal control problems, it is necessary that all personnel involved are thoroughly familiar with what is initial attack and what is so-called campaign fire action. Use of the planes on initial attack is funded from the $20,640 mentioned above. The continued use of the same planes after the initial attack phase is funded from emergency fire suppression funds (formerly 3VK). For the purposes of this program, initial attack is defined in either of the following two ways: 1) any aerial attack made on a going fire prior to arrival of organized ground suppression force (pumper crews or dozers) or, 2) any aerial attack made on a going fire within 30 minutes air travel time regardless of number of ground forces reaching the fire within that time when the Hanna index is 51 or more.

C. Communications.

The specially purchased handi-talkies will not be available during the greater part of the 1958 operation. In order to give communications to the planes each one will be assigned one of our new 1-watt handi-talkies which transmit and receive on 151.385. This will mean that there will be communications from plane to plane, from tankers to coordination plane or patrol planes, and from coordination plane and tankers to any of our ground forces having radio with the 151.385 receiver. In addition, the coordination plane will be equipped with a mobile radio on the 172.375 frequency. (Same as patrol planes.) As soon as new equipment is received and planned conversions made, the tankers will also be able to talk direct when within reasonable distance with all ranger unit headquarters except Fortuna.

VI. Dispatching Actions and Responsibilities.

A. General. The area of potential initial attack action by the two groups of 2 planes each overlaps each other in a considerable area. In most instances the planes based in Lake County will be closer to any fire occurring in Lake County than will those based in Mendocino, and vice versa.

B. For such fires occurring in the ranger unit where the planes are based, the ranger unit dispatcher will dispatch the 2 planes direct under the provisions outlined above under initial attack principles.

C. On those occasions where all 4 planes are needed in either Mendocino or Lake counties, within the mutual attack area, the Lake dispatcher will dispatch his own 2 planes and then call the Mendocino dispatcher for dispatch action on the 2 Mendocino planes. The reverse would hold true for those fires occurring in Mendocino within the mutual attack area.

D. Requests by the Forest Service will be sent direct to the ranger unit dispatcher whose planes are closest to the U.S.F.S. fire, or to both dispatchers if 4 planes are requested.

E. For fires occurring and qualifying for initial attack action in Humboldt, Napa and Sonoma ranger units, dispatching will be accomplished by the Lake or Mendocino dispatcher, as the case may be, upon receipt direct of a request from the dispatcher of Humboldt, Napa or Sonoma.

F. In all cases, and as soon as possible following the dispatch of the tankers, information relative to their activation will be relayed by the sending dispatcher to the district office and to the ranger unit where the other squadron is based.

G. It is the intent that the coordination plane with the project leader be dispatched to every fire possible within the CDF jurisdiction where aerial tankers are used. Normally the project leader will be based at Hoberg's but on occasion may not be right at the airport. It shall be his responsibility to keep the local ranger unit dispatcher informed of his location and means of communication and then that dispatcher will inform the project leader <u>immediately</u> of any activation of any of the tankers.

H. On days where the Hanna fire risk is 51 or more, and following the above procedures, all 4 planes will be dispatched to qualifying fires occurring within their mutual initial attack area.

I. For fires occurring outside the mutual initial attack area, but within the initial attack area of one squadron and where the second squadron may be required, dispatch procedures will be for the ranger unit having the fire to place his request for the second squadron with the district office.

J. For fires occurring more or less simultaneously it shall be the ranger unit dispatcher's responsibility to determine to which fire to send the planes if both fires are within his ranger unit. Should there be more than one fire occurring simultaneously, but in different ranger units, the determination of which fire to attack shall be made by the district office in cooperation with the project leader.

K. When planes are activated on initial attack and are subsequently used on follow-up action on the same fire, there is a potential that a new fire might occur. When the new fire is within the ranger unit having the plane action on the other fire, it shall be the responsibility of the ranger unit dispatcher to determine if the plane should be pulled from the going fire for attack purposes on the new one. When the new fire occurs in a different ranger unit, the district office, through the project leader, will determine if the plane should remain on the going fire or should be released for assignment to the new one.

L. To assist in making a determination as to which fire to attack when there are duplicate requests, ranger unit dispatchers should be prepared to immediately assign a "Priority number" to a fire after its initial report based upon the following guide lines:

   1. High values (timber or critical watershed); more than 1½ hours travel time by ground crews; rough topography; absence of natural barriers; brush burning index (actual or predicted) 15 or more; excellent possibility of campaign fire developing.

   2. Medium to high values; 1 hour to 1½ hours travel time by ground crews rough topography; some natural barriers; brush burning index 10 to 15; good possibility of campagin fire developing.

   3. Medium values; 1/2 hour to 1 hour travel time by ground crews; topography allows use of dozers; some natural barriers; brush burning index 10 to 15; fair chance of campaign fire developing.

   4. Low values; over 1/2 hour travel time by ground crews; not too much resistance to conventional fire control actions; brush burning index less than 10; small possibility of campaign fire developing.

   5. Not otherwise classified. Lowest priority.

   The foregoing are <u>general</u> guide lines and <u>all</u> criteria may not exist in all cases.

M. After the tankers return to their home base from a fire action, the dispatchers previously notified of their assignment should be notified that they are back in base.

N. Determination of whether or not the tankers would standby on a particular day is the responsibility of the district dispatcher, acting upon advice of the ranger units as necessary. The preliminary decision can be made the previous evening based on fire risk trends, etc., and confirmed the following morning upon receipt of the 8:30 a.m. fire weather forecast. On occasions when it is very obvious that the next day's fire risk will be lower than 31, release from standby may be accomplished in the evening. There may be occasions when, due to existing fires, the tankers may be held in readiness even though the fire risk is a few points below 31. This determination will require close coordination and cooperation between the district dispatcher, ranger unit dispatchers and project leader.

O. In addition to Borate set-ups to be established at the 2 air tanker bases, Borate set-ups will be established at Covelo and Dinsmoor airports. It will be possible to use these tankers from these locations on initial attack if the refill time can be shortened. The determination of which refill tanker port is to be used on any fire action must be determined by the requesting dispatcher, or the dispatcher responsible for the particular fire concerned.

P. There will be one portable Borate mixing unit based at district headquarters. This unit will consist of a stake-side, radio 1019, a Borate mixer, water pumps, Borate pump and necessary hose and valves. Also available will be 8 tons of Borate.

The portable unit will be available to any ranger unit having need for it upon request to the district office.

Emery Sloat
7-15-58

Division of Forestry
District V

September 16, 1958

AERIAL TANKER INITIAL ATTACK PROGRAM

SPECIAL GUIDE LINES AND FLIGHT RULES FOR PROGRAM

On most flights during this program, there will be many aircraft of various types operating on their assignments at the same time in a small air area over a fire. To assist in the prevention of an air collision, the following flight rules will be observed by all pilots working for Division of Forestry and by all CDF employees when more than one aircraft, of any type, is operating on a fire in the Central Coast District.

1. Dispatching action will aim towards having a drop coordinating plane (DROPCO) on fires before aerial tankers arrive.

2. DROPCO plane will advise unit dispatcher of his arrival at fire. A report of conditions on fire will be radioed to unit dispatcher as soon as possible.

3. Additional aircraft except aerial tankers will announce by radio their presence when approaching fire area at not less than five miles distance. DROPCO will acknowledge.

4. DROPCO plane will maintain flight altitude of 1,000 feet above fire area when aerial tankers are operating, except when making a drop of his own.

5. Any other observation aircraft will maintain a flight altitude of at least 2,500 feet above fire area.

6. Aerial tankers will stay below 500 feet elevation above the fire area while making observations and drops. Dependent on topography and air turbulence, aerial tankers may exceed this elevation on approach and when leaving the fire area, but not within one mile of the fire.

7. If air turbulence, topography, smoke conditions, or fire conditions, are such that the foregoing flight elevations cannot be maintained, the aircraft having to change to a higher or lower altitude must report the change to the DROPCO plane and receive a confirmation before changing.

8. All flight patterns for the DROPCO plane and other aircraft on patrol and observation operations will be in a clockwise (right hand) direction. If, for reasons of

topography, visibility, etc., another pattern is desirable, the aircraft wishing the change shall notify the drop coordinator and receive confirmation before changing. If the drop coordinator wishes to change from a clockwise pattern, he will notify any other aircraft operating on the fire or approaching.

9. Rotary wing aircraft will not operate within two miles of an initial attack aerial tanker operation on a fire unless the DROPCO plane has been notified and has established a plan of operations, which includes radio communication between DROPCO and rotary wing aircraft.

10. Aircraft, except aerial tankers making drops, will maintain a clear visibility of at least one mile at all times.

11. Initial attack aerial tankers will have priority of travel routes and altitudes to and from the fire area. Aerial tankers will return to the airport at a different altitude than used for approach of the fire, to be decided by the pilots prior to, or at the start of, each fire operation.

12. Initial attack aerial tankers will have priority of landing and take offs when operating on fires.

13. CDF employees will instruct pilots as to their assignment, however, the final decision as to the safety of operation rests with the pilot and no pilot will attempt to carry out any assignment that the pilot feels is not safe. A complete orbit of the fire area prior to the drop is mandatory for each aerial tanker prior to every drop. Avoid excessively dense smoke in which there may be a lack of oxygen and subsequent power loss.

14. When operating on U. S. Forest Service fires under the initial attack program, these rules will be observed unless changed by Forest Service. Forest Service personnel may act as observer in DROPCO. Smoke jumpers or helicopter crews may be used and will require additional orders issued by Forest Service.

15. Initial attack aircraft on a fire will use radio calls as follows:

DROPCO-5	(Cessna 180 Observation-Tanker, Larry Young Observer)
STEARMAN 44	(Lou Ortali, pilot)
STEARMAN 17	(Stewart Kunkee, pilot)

State of California
Department of Natural Resources
Division of Forestry

Contract Specifications for the Use of
Aircraft in Initial Attack Forest Fire Suppression
June 25, 1958

I. General Intent and Provisions

The Division of Forestry, hereinafter known as the State, intends to utilize fixed wing aircraft known as "air tankers" in an experimental initial attack forest fire operation in such a manner as to evaluate their effectiveness under such use. To meet the intent the contractor(s) will be required to furnish aircraft, pilots, fuel, oil, supplies and services as needed and as specified. This experimental initial attack forest fire operation shall be based on two requirements, i.e., standby of aircraft and pilots, and flight time.

a. Standby shall be defined as that time which the contractor(s) shall supply aircraft and pilot(s) at the request of the State to be available at designated airport(s) on ready alert for immediate dispatch to forest fires which have just been detected.

b. Flight time shall be defined as any time when at the request of the State, the aircraft is airborne to meet the requirements of the initial attack air program.

II. Area of Use:

The area of use shall include portions of El Dorado, Amador, Calaveras, Tuolumne, Mariposa Counties, Stanislaus and El Dorado National Forests, and such other adjacent areas as selected by the State.

III. Airport Bases:

The Columbia airport in Tuolumne County will be the primary base of operations. Other airports may be used as sub-bases should the need arise. Any costs incurred incidental to the use of airports shall be paid for by the contractor(s).

IV. Duration of Program:

Overall period shall be from approximately July 4, 1958 to October 15, 1958.

V. Operating Periods:

During the initial attack program (requested standby or actual flight) operating periods will be selected by the State based on existing or predicted fire conditions. It is the intent of the State to use these aircraft as much as possible within these operating periods (dependent on the occurrence of fires) to provide a sound base for statistical evaluation of their effectiveness. It shall be understood by the contractor(s), that during the selected initial attack operating periods the aircraft will be used for no purpose other than initial attack unless released by the State. The aircraft and pilots hired under the terms of this contract may be released to operate on State Fires which have extended beyond the initial attack stage, for initial attack on U. S. Forest Service fires within limits established by the State, or on U. S. Forest Service fires which have extended beyond the initial attack stage. Any charges for such use of these aircraft will be handled separately by the State or the U. S. Forest Service, and will not be deemed a part of this contract.

VI. Number of Aircraft and Pilots Required:

A total of three aircraft (one Grumman TBM "air tanker," one Stearman "air tanker," and one high wing - four place, "observation plane") in accordance with these specifications, including not less than one pilot for each aircraft and other allied services as required, will be furnished by the contractor(s) for this program. NOTE TO BIDDERS: the State recognizes the difficulty in obtaining the full complement of specified aircraft from one contractor, therefore, bids will be considered from those who can supply any portion of the total number of aircraft and pilots required.

VII. Distribution of Aircraft:

The aircraft will be equally divided between the primary airport as designated and may be further divided to other selected airports within the above described area as deemed necessary by the State.

VIII. Expenditure:

The total expenditure for aircraft, pilots, and allied services for initial attack under this program shall not exceed $22,795.

IX. General Operations:

a. It is understood that the hourly rates paid shall include all compensation for operation and maintenance of the aircraft and for lodging and subsistence incurred by the pilot(s).

b. Attached to these specifications is a copy of "State of California Standard Agreement" form No. 2, which will be the formal contract document between the contractor(s) and the State. Each bidder's attention is called to the general provisions on the reverse side of this form which are applicable to the formal contract.

c. During the period of the contract the aircraft and pilots will be at the designated airport(s) at the request of the State on an immediate dispatch "standby" basis. The times of standby to be dependent on existing or predicted fire conditions as follows:

Fire Risk Extreme: or Very High	Standby, 0800 P.D.T. to sunset, every day. (Estimated to be approximately 15% of the total days).
Fire Risk High:	Standby, 1200 P.D.T. to 1 hour before sunset, 5 days a week but to include Saturdays, Sundays and all holidays. (Estimated to be 35% of the total days).
Fire Risk Moderate:	No standby, but available for dispatch within 10 minutes to fires starting in high values, or, in inaccessible locations requiring more than one hour travel time of existing Division of Forestry ground crews. (Estimated to be 45% of the total days).

To meet these provisions the plane(s) shall be loaded with the specified gasoline supply, and the fire retardent or water as selected by the State.

d. Because of the nature of this program, time is of the essence. Pilot personnel shall make every effort to keep get-away time to the absolute minimum. "Get-away" time on initial dispatch shall not exceed 5 minutes (except on moderate fire risk days which will be 10 minutes) unless due to unavoidable circumstances beyond the control of the contractor(s).

e. The contractor(s) will furnish any transportation that may be needed for his pilots use between his place of lodging and his assigned dispatch airport(s).

f. The State will make available a radio with antenna. Contractor(s) agree(s) to permit installation of the radio and antenna in the aircraft. State will furnish batteries and necessary maintenance on the radio.

g. Contractor(s) agree(s) to have his pilot(s) keep such simple records of activity as may be required by the State.

h. It is mutually understood that the program is operating under the direction of the field officers of the State. In those cases where a pilot may be asked to make a drop under extremely hazardous conditions, the final decision for complying with the request shall rest with the pilot.

i. The terms of this contract pertain only to the initial attack phase of the State's fire suppression operations in the area described.

j. The State reserves the right to determine if the services performed in regard to availability, get-away time and fire control action are adequate and, if not, to terminate this contract upon delivery of written notice.

k. The contractor(s) may terminate the contract by serving written notice to the State at its District office, (1001 Jed Smith Drive, Sacramento).

l. It is mutually agreed and understood that this agreement may be modified by mutual consent of the parties hereto.

m. It is desirable that the same pilot remain assigned to the same plane during the course of this contract. With the approval of the State the contractor(s) may substitute an alternate pilot to cover the services in the event of illness or undue fatigue of a regular pilot.

n. For services provided under this contract the contractor(s) shall submit invoices in triplicate weekly to the Division of Forestry, 1001 Jed Smith Drive, Sacramento, on either letterhead or billhead or, if on plain paper, properly signed with title.

o. In order to effect better understanding and to improve the efficiency of the operation, it is mutually agreed that a training session will be conducted by the State to include both pilot personnel and State personnel prior to activities of the planes on wildfire control.

X. Aircraft Specifications (minimum)

a. The aircraft (except the observation ship) shall be certified for restricted use by C.A.A. and shall be airworthy at all times during the contract. The observation plane to be certified by C.A.A. for the purpose intended and to be airworthy.

b. Horsepower ratings shall be not less than:

Stearman - 450 H.P.

T.B.M. - 1900 H.P. (Sea-level-Lo-Blower, 49" manifold pressure at 2800 R.P.M.)

Observation Plane - 225 H.P.

The aircraft and engine(s) shall be in such condition so as not to require a normal periodic overhaul during the contract period. Before substitution of aircraft is made for any reason approval must be obtained from the State.

c. The payload capacitites of the Stearman and the T.B.M. shall be:

Stearman - at a density altitude of 6300 feet (3000' pressure altitude at 100°F) shall be not less than 100 gallons of a fire retardent mixture weighing 10.1 lbs. per gallon and the available capacity shall be not less than 150 gallon.

T.B.M. - At a density altitude of 6300 feet (3000' pressure altitude at 100°F) shall be not less than 400 gallons of a fire retardent mixture weighing 10.1 lbs. per gallon and the available capacity shall be not less than 600 gallon.

d. The fuel capacity for the tanker aircraft shall provide for not less than two hours flight at cruising speed and the fuel capacity for the observation plane shall provide for not less than four hours flight at cruising speed.

e. The aircraft shall be equipped with not less than the following functioning instruments:

Stearman	T.B.M.	Observation Plane
1. Engine group; oil temperature gauge, oil pressure gauge, fixed pressure gauge.	1. Same	1. Same
2. Air speed indicator	2. Same	2. Same
3. Rate of climb indicator	3. Same	3. Same

(continued)

Stearman	T.B.M.	Observation Plane
4. Sensitive altimeter	4. Same	4. Same
5. Magnetic Compass	5. Same	5. Same
	6. Gyro-compass	6. Same
	7. Hydraulic System Pressure gauge	7. Tachometer
	8. Tachometer	8. And any other instruments required for I.F.R.

f. The Stearman tank to contain the drop material shall have adequate venting and a means of measuring the quantity of liquid in the tanks such as a sight gauge or stick. The gate shall be a quick release, free swinging type with the hinges at the leading edge and shall have an outlet area of not less than 175 square inches and shall be not less than 10 inches in any one dimension. (Preference will be given, other factors being equal, to bidders offering gates having substantial larger outlet areas). The gate shall be constructed so that it may be closed from the cockpit while in flight. The TBM tank to contain the drop material shall have adequate venting and a means of determining the quantity of liquid in the tank. The tank shall be divided longitudinally into two equal size compartments, each compartment to have a quick release, free swinging type gate hinged longitudinally at each outer edge, each gate to have an outlet area of not less than 700 square inches and to be not less than 8 inches in any one dimension. The controls for the gates shall be such as to permit opening the gates individually or simultaneously and to close the gates while in flight. The State reserves the right to inspect all aircraft, components and equipment which the bidder proposes to furnish under this contract.

XI. Pilot Qualifications:

1. Currently valid commercial pilot's license.

2. A minimum of 500 hours of agricultural flying or 200 hours of timber spraying, cargo dropping, seeding, baiting, fish planting, patrol, or similar low-level mountain flying experience (total of all flying experience--1,000 hours).

3. The State reserves the right to test the qualifications and proficiency of the named pilots offered by the bidder in response to these specifications.

The above aircraft and pilots shall be available for inspection and appraisal not later than July 1, 1958.

The State also reserves the right to retest the pilots proficiency at any time during the term of the contract or to test the proficiency of any pilot proposed for replacement should such replacement become necessary.

Air Tanker Daily Check List

This form to be completed each morning as soon as air tankers are placed on standby and upon return from each air tanker operation. To be completed by check marks where applicable.

General Operation Check - By CDF Observer

Date _____ Area ____________________________ Predicted Burning Index ____

Standby condition: Low ___ Moderate ___ High ___ Very High ___ Extreme ___

Reason for above selected condition if not consistent with Burning Index: ____

____

____

Mixing Operation

Borate sacks on hand ___ (est.) Borate storage tanks filled to standard ________ Inches of free water on top of slurry _____ (inches)

Hose connection secure: Tank to transfer pump ____ Transfer pump to nozzle _______ Check mixer pump for operation condition: Fuel supply ____ Oil supply _______

Air Tanker Check - By Contract Pilot

Moderate Fire Risk:

Visual check of plane:	Auxiliary power unit check:	Cockpit Check:
Control surfaces ____	Gasoline ________	Start A.P.U. ______
Tires ________	Oil _______	Fuel Quantity ________
Oleo struts ______		Oil level ________
		Radio Comm. OK _______

Borate tank: Loaded ____ Any undue leakage ____

High, Very High, or Extreme Fire Risk:

Aircraft engine warmup at standby time ______

All instruments functioning ___________

(FRONT)

AIR TANKER PILOT & OBSERVER REPORT

Date ________

Heading ____ ° Miles ____ From ____________ Airbase; Fire is ____ Mi. N,NE,E,SE,S,SW,W,NW of Landmark ____________

Agency ________ Unit ____________ Pilot ______________

Plane No. ____________

	Initial Attack 1st Drop	2nd Drop	3rd Drop	4th Drop	Campaign Fire Others
Time Airborne					
Time Arrival on Fire					
Time of Drop					No.Drops*
Gallons of Drop					Total*
Height of Drop					Av.Ht.
Air Speed					Av.Spd.
Size of Fire(Acres if $\frac{1}{4}+$ or "spot")					Acres
	CHECK APPROPRIATE SPACE BELOW				
Drop Made On (Head					No.
(Flank					No.
(Rear					No.
Drop Made (Ahead of Fire Edge					No.
(On Edge of Fire					No.
(Inside of Fire Edge					No.
Drop Made From (Down Wind					No.
(Up Wind					No.
(Cross Wind					No.

*Do not repeat drop data reported for 1st four drops. If drops are not of a retardant solution but are plain water, so note. See over for additional data and comments.

(BACK)

TO BE COMPLETED BY PILOT IF NO OBSERVER FLYING FIRE:

		1st Drop	2nd Drop	3rd Drop	4th Drop	Others
Fire Behavior at Time & Place of Drop	(Creeping					
	(Running					
	(Spotting					
	(Crowning					
Fire Behavior After Drop	(Fire Stopped					
	(Burning Through					
	(Drop Line					
	(Fire Spotted					
	(Over Line					
	(Fire Flanked					
	(Line					

Comments regarding topographic problems, power line or smoke hazards, communication problems, turbulence, etc., effecting accuracy and/or effectiveness of drop.

Agency____

Fire No.__

Time arriv

Time of ac

Were air d

Effect of

If drops n

1. Fire be

Cre

Rur

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2. Fire be

Fir

Fir

Fir

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AIR TANKER ACTIVITY - GROUND CREW REPORT (FRONT)

Agency______ Unit ______________ Date of Fire______ Name of Fire ______________

Fire No.______ Location: Sec.______ Twp.______ Rge ______ Elevation ______________

Time arrival of ground unit ________ Pumper ☐ Dozer ☐ Patrolman ☐ Other ☐

Time of action by ground unit ______ Type, if other than above ______________

Were air drops made prior to arrival of 1st action by crew?_____ If so, how many?__________

Effect of above drops: Fire held by drops ____________

Fire burning through line ________

Fire spotted over line __________

Fire flanked line ______________

If drops made after ground attack:

1. Fire behavior at point of drop(s)	1st Drop	2nd Drop	3rd Drop	4th Drop	Others
Creeping					
Running					
Crowning					
Spotting					
2. Fire behavior after drop(s)					
Fire stopped after drop No.					
Fire slowed for___ No. of hours	hrs	hrs	hrs	hrs	hrs
Fire burned through after drop No.					
Fire flanked line after drop No.					
Fire spotted over line after drop No.					

(BACK)

Burning factors at fire (if available): Time taken ____________

Wet bulb temp. ______ Dry bulb temp. ______ Wind speed __________

Slope at drop site ____________%

Veg. type contributing most to rate of spread: Grass ___ Brush ___ Timber ________

Effectiveness: (see instructions)

Reasons for effective drops:

Reasons for partially effective drops:

Reasons for wholly ineffective drops:

If ground crews on fire prior to drop, was air attack needed? Yes ___ No ____

Could 2 or 3 additional ground units have done the job as effectively? Yes ___ No ____

Explain:

AIR ATTACK - SUMMARY REPORT

1. Agency______ 2. Unit________ 3. Date__________________ 4. Fire Name________________

5. Fire No.____ 6. Location: Sec.___ T.__________ R.__________ 7. Elevation__________

8. Fire Reported________ (Time) 9. Plane Dispatched:________ (Time) 10. First Plane Airborne:______ (Time)

11. Was an air coordinator on scene during air attack? Yes______ No______

12. No. of drops he observed: 1st:_____ 2nd_____ 3rd_____ 4th_____ Others (No.)_______

13. Air Attack 1/

	Stearman (a)	N3N (b)	TBM 2/ (c)	Other (d)	:	Time (e)	Height (f)	Speed (g)	Fire Size (acres) (h)
1st drop					:				
2nd drop					:				
3rd drop					:				
4th drop					:				
Others (No. of each)					:		(Av.)	(Av.)	(Av.)

1/ Check plane type or name in case of "other", show time, estimated height, etc.

2/ Note if drop consists of one third total load (1/3), half load (1/2), or full load (1).

14. Total drops made on initial attack:_______ 15. Total made on campaign fire________

16. Total gallons of retardant 3/__________, of water __________

3/ Indicate if other than borate.

17. Ground attack 4/

	Hand Crew (a)	Pumper Crew (b)	Patrolman (c)	Dozer (d)	:	Time (e)
1st unit in action					:	
2nd unit in action					:	
3rd unit in action					:	

4/ During air initial attack stage only. Check appropriate type of unit and show time.

18. Were ground crews making effective initial attack upon arrival of air unit?
Yes______ No______

19. If yes, could they have been reasonably expected to control fire without air aid?
Yes______ No______

(see over)

20. If no, what were factors contributing to difficult control?

a. Fire danger rating area No.________ b. Average B.I. for this area______

c. B.I. at fire site______

d. Topographic problems:

e. Vegetation problems:

f. Other:

21. Explain factors contributing to success, or failure, of air attack: (communications, individual pilot ability, mechanical factors, physical or mental hazards, location of drop with respect to fire head or to fire edge, turbulent winds, lag in ground followup, etc.)

a. Reasons for effective drops:

b. Reasons for partially effective drops:

c. Reasons for ineffective drops:

22. Could 2 or 3 additional conventional units have been reasonably expected to control this fire without air attack? Yes______ No______

23. Air attack filmed? Yes______ No______, Film identification No.____________

Instructions: This summary to be completed by Air Officer, Observer, Fire Boss or Dispatcher from information gathered on crew activity, reports, fire reports, etc., and from special air attack reports filed by the air tanker pilots. Upon completion route through normal agency channels for forwarding to the California Forest and Range Experiment Station.

FLIGHT - BORATE RECORD

FIRE NAME ______ NO. ____ COUNTY ____________ DATE ________

PLANE TYPE ___________ PLANE NO. __________

	1st Trip	2nd Trip	3rd Trip
Time Up			
Time Down			
Total Flight			
Gals. Load			

	4th Trip	5th Trip	6th Trip
Time Up			
Time Down			
Total Flight			
Gals. Load			

PLANE TYPE ___________ PLANE NO. __________

	1st Trip	2nd Trip	3rd Trip
Time Up			
Time Down			
Total Flight			
Gals. Load			

	4th Trip	5th Trip	6th Trip
Time Up			
Time Down			
Total Flight			
Gals. Load			

REMARKS:

Fl:4 (8-22-58)

____
Timekeeper

Exhibit H

1.

2.

3.

4.

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11.

12.

13.

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FIGHTING FOREST FIRES

WITH AIR TANKERS

PART TWO: 1959

by C. B. Phillips

Contents

A Study of the Use of Air Tankers on Forest Fires in 1959 by the California Division of Forestry

INTRODUCTION

Since 1955 the use of air tankers on forest fires by forest fire-fighting agencies has expanded greatly. Concurrent with this expansion has been the problem of how best to integrate the air tanker into existing fire control organizations. Almost at once the questions of how, when, and where to use this new tool most efficiently, effectively, and economically presented themselves for answering. Continued evaluation of the use of air tankers on forest fires has been made by the firefighting agencies in an effort to find the best answers (2, 3, 5, 12, 13)[1/].

In 1959 the California Division of Forestry conducted an experiment designed to provide data which would permit the refinement of air tanker use criteria and which would expand the findings of previous years' operations (7, 8, 11). The limited budget provided for this program allowed for contracting of a certain number of aircraft and pilots and for purchasing of fire retardant materials. Supervising and facilitating personnel had to be provided by the Division from its regular fire control forces, thus sacrificing the performance of normal duties by these people.

SUMMARY

The experiment involved a basic team of four air tankers which moved throughout the fire season to three different administrative districts in the state (Fig. 1), thus providing data of use under a variety of fire conditions, fire weather, topography, and fuel types. In addition other aircraft were dispatched from more permanent bases throughout the state. The principal objective was to use these aircraft on initial attack, although they were also used on follow-up action if the need was established.

The activities of the air tanker pilots while in flight were controlled and directed as often as possible by drop coordinators, who were experienced fire control men and who flew in separate observation type aircraft. Personnel were provided at each airport facility to mix retardant slurry, to load aircraft during fire action, and to maintain records of air tanker use.

Data were obtained in several ways about air tanker use on forest fires and about the behavior of the particular fires. Analysis of the data resulted in the following recommendations or improvements to existing guidelines:

1/ Underlined numbers in parentheses refer to Literature Cited, page 46.

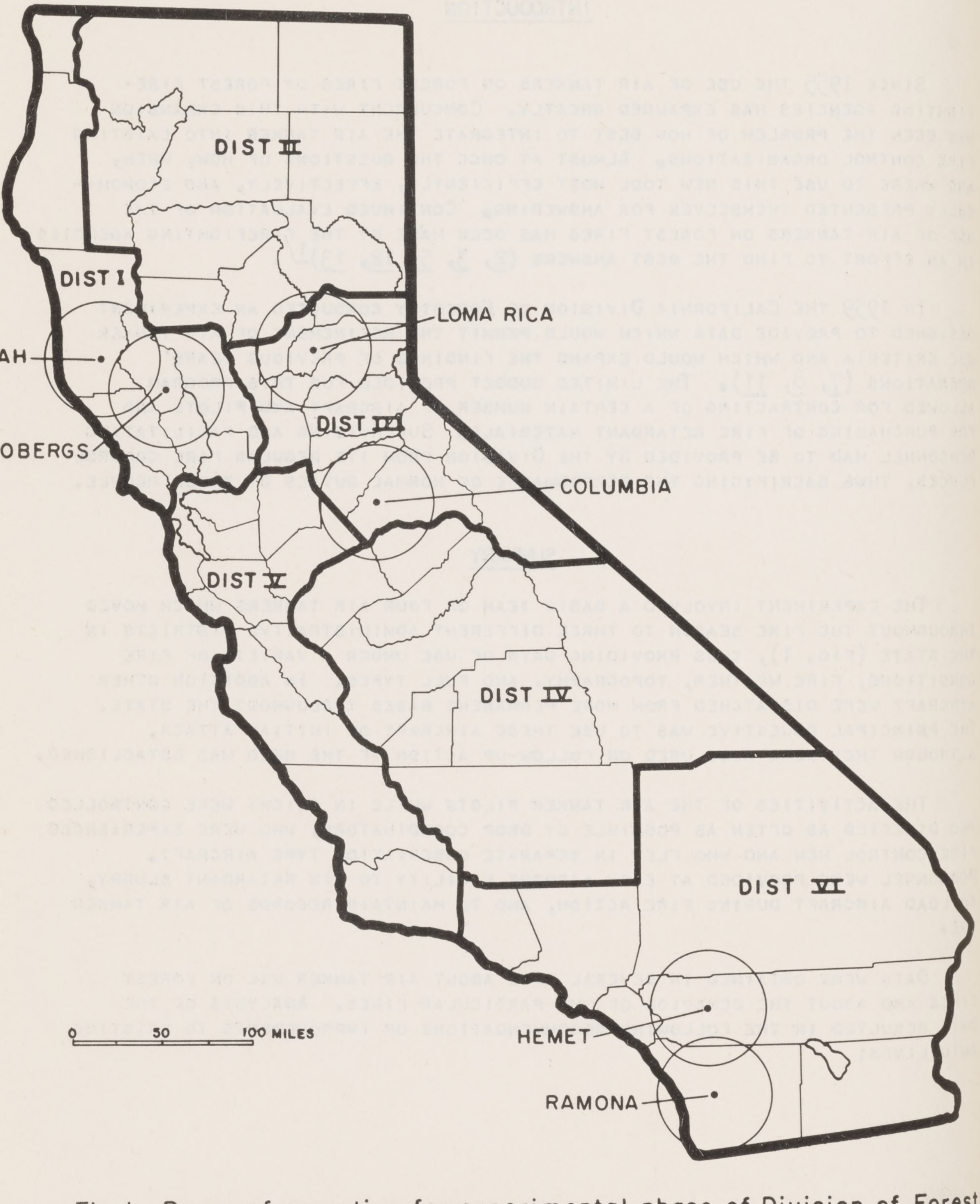

Fig. I Bases of operation for experimental phase of Division of Forestry air tanker program, 1959. Circles represent 30 miles of radius.

TANK AND GATE DESIGN:

1. WITHIN PRESENT KNOWLEDGE GAINED BY EXPERIMENTATION IT IS FELT THAT TANKS SHOULD BE DESIGNED WITH NO PROTRUDING LIPS, FLANGES, OR OTHER AREAS OF ENTRAPMENT. GATES SHOULD BE AS LARGE AS THE TANK BOTTOM WITH NO OBSTRUCTIONS TO THE FLOW OF RETARDANT.

CENTRAL DIRECTION:

1. SINCE AIR TANKERS CAN EASILY RANGE ON INITIAL ATTACK BEYOND RANGER UNIT ADMINISTRATIVE BOUNDARIES, SOME DEGREE OF CENTRAL DIRECTION FROM DISTRICT HEADQUARTERS MUST BE MAINTAINED.

PILOT PROFICIENCY:

1. MINIMUM EXPERIENCE STANDARDS ESTABLISHED IN THE PAST SHOULD BE MAINTAINED.

2. PILOTS NEW TO THE FIRE CONTROL JOB WILL REQUIRE PERHAPS A MINIMUM OF 50 DROPS BEFORE THEY BECOME PROFICIENT.

3. EXTREME COMPETITION BETWEEN EXPERIENCED AND INEXPERIENCED PILOTS SHOULD BE DISCOURAGED TO PREVENT POSSIBLE ACCIDENTS.

FACILITIES:

1. ADEQUATE PERSONNEL AND FACILITIES ARE THE KEYS TO DECREASING DOWN-TIME OF AIRCRAFT ON A SUSTAINED FIRE CONTROL OPERATION.

2. THERE SHOULD BE A STORAGE CAPACITY OF AT LEAST 10,000 GALLONS OF RETARDANT WHERE SMALL AIR TANKERS ARE USED AND AT LEAST 30,000 GALLONS WHERE LARGE TANKERS ARE USED.

3. A TRANSFER PUMP CAPABLE OF DELIVERING 500 GALLONS PER MINUTE IS DESIRABLE.

4. MIXING AND LOADING AREAS SHOULD BE ADJACENT BUT DISTINCTLY SEPARATED. BOTH AREAS SHOULD BE PAVED, HAVE GOOD DRAINAGE, AND HAVE WATER UNDER PRESSURE FOR REMOVING SPILLED AND EXCESS RETARDANT.

5. BATCH-TYPE MIXERS SHOULD BE PROVIDED FOR LARGE, PERMANENT AIR TANKER BASES.

6. BOTH OFFICE AND LOUNGING FACILITIES SHOULD BE PROVIDED AND BE SOMEWHAT SEPARATED.

7. ONLY AIRPORTS APPROVED FOR SPECIFIC PLANE TYPES BY THE DIVISION'S SACRAMENTO HEADQUARTERS PERSONNEL SHOULD BE USED.

TRAINING:

1. BECAUSE OF THE COST AND TECHNICAL ASPECTS OF THE AIR TANKER PROGRAM, ALL PERSONNEL INVOLVED MUST RECEIVE INTENSIVE TRAINING. SELECTED TRAINING PROGRAMS FOR THE DIFFERENT JOB CLASSES OF

PERSONNEL ARE SUGGESTED IN THIS REPORT.

PLANNING AN AIR TANKER PROGRAM:

1. MANY FACTORS MUST BE CONSIDERED PRIOR TO SELECTING AIR TANKER PLANE TYPES FOR SPECIFIC LOCATIONS. AIR TANKER TYPES VARY CONSIDERABLY IN THEIR CAPACITY TO DELIVER RETARDANTS EFFECTIVELY, DEPENDENT ON FACTORS OF 1) DISTANCE TO THE FIRE, 2) TOPOGRAPHY, 3) NORMAL FIRE BEHAVIOR, ETC.

2. EACH DISPATCHER'S OFFICE SHOULD HAVE AN AIR OPERATIONS MAP WHICH WILL DELINEATE 1) THOSE AREAS WHERE AIR TANKER USE WILL ALMOST ALWAYS BE EXCLUDED, 2) THOSE AREAS WHERE TANKERS WILL ALMOST ALWAYS BE DISPATCHED IMMEDIATELY ON INITIAL ATTACK, AND 3) THOSE AREAS WHERE AIR TANKERS MAY OR MAY NOT BE USED DEPENDING UPON THE COMBINED EFFECT OF SEVERAL FACTORS. AN AIR OPERATIONS MAP SHOULD ALSO INCLUDE AT LEAST THE LOCATION OF DEEP, NARROW CANYONS, POWER AND TELEPHONE LINES OVER 25 FEET IN HEIGHT, AND VEGETATIVE TYPES.

3. NO AIR TANKER PROGRAM SHOULD BE ATTEMPTED WITHOUT PLANNING AND PROVIDING AN ADEQUATE COMMUNICATIONS SYSTEM, INCLUDING A SEPARATE AIR RADIO NET.

4. CONTINUAL EVALUATION OF AIR TANKERS AND PILOTS SHOULD BE MADE TO ELIMINATE THOSE WHICH MAY BE FOUND LEAST EFFICIENT OR TOO SUBJECT TO ACCIDENT.

INITIAL ATTACK DISPATCHING:

1. AIR TANKERS SHOULD BE DISPATCHED THE SAME AS ANY OTHER TOOL.

2. IF CONDITIONS INDICATE THAT AIR TANKERS SHOULD BE USED, THEY SHOULD BE DISPATCHED WITHOUT DELAY.

3. AIR TANKERS ARE MOST EFFECTIVE IN GRASS AND LIGHT BRUSH, WHEN THERE ARE LIGHT OR NO WINDS, ON FLAT OR ROLLING TOPOGRAPHY, ON FIRES STARTING AFTER 1400 P.D.T., AND WHEN DISTANCE TO THE FIRE FROM THE AIRPORT IS 20 MILES OR LESS.

4. AIR TANKERS ARE LESS EFFECTIVE IN DENSE BRUSH OR TIMBER, WHEN WINDS ARE OVER 20 MILES PER HOUR, ON STEEP TERRAIN, ON FIRES STARTING BETWEEN 1000 AND 1400 P.D.T., WHEN DISTANCE TO THE FIRE FROM THE AIRPORT EXCEEDS 20 MILES, AND WHEN THE AIR IS TURBULENT. DEEP SHADOWS OCCURRING IN EARLY MORNING OR LATE AFTERNOON HOURS CAN ALSO DECREASE THE PILOTS' ABILITY TO DROP ACCURATELY.

5. AIR TANKERS ARE OFTEN LIKELY NOT TO BE NEEDED WHEN THE BURNING INDEX IS BELOW 9, THE AIR TEMPERATURE IS BELOW 80°F., THE FIRE IS CONFINED TO GROUND FUEL IN DENSE TIMBER OR DENSE WOODLAND (ESPECIALLY ON THE SHADY SLOPE, LATE IN THE DAY), CREW GETAWAY AND TRAVEL TIME IS LESS THAN 10 MINUTES, AND WHEN FIRES START FROM A WET LIGHTNING STORM IF GROUND FORCES

COULD HANDLE THEM ALL WITHIN THE FIRST 24 HOURS.

AIR-GROUND COORDINATION:

1. AIR-GROUND COORDINATION IS ABSOLUTELY ESSENTIAL TO SUCCESSFUL AIR TANKER ACTIVITY.

2. AN ADEQUATE COMMUNICATIONS SYSTEM IS A NECESSITY FOR GOOD COORDINATION.

3. A DROP COORDINATOR IS NEEDED TO CONTROL AND DIRECT AIR TANKER ACTIVITY. HE SHOULD BE A STRONG SUPERVISOR AND AN EXPERIENCED FIRE CONTROL TECHNICIAN AND SHOULD HAVE SUFFICIENT ADMINISTRATIVE RANK TO COMMAND RESPECT OF BOTH GROUND AND AIR FORCES.

4. THERE MUST BE A CLOSE WORKING RELATIONSHIP BETWEEN THE FIRE BOSS AND THE DROP COORDINATOR ON A FIRE AT ALL TIMES.

5. IF THERE ARE A SERIES OF SEPARATE FIRE STARTS OCCURRING IN THE SAME GENERAL TIME AND AREA, THE AIR TANKERS CAN NORMALLY BE MOST PROFITABLY USED ON THE SMALLER, MOST ISOLATED FIRES.

6. CRITIQUES OF ACTION TAKEN BY AND BETWEEN GROUND AND AIR PERSONNEL ARE HIGHLY DESIRABLE FOLLOWING EACH FIRE ACTION IN ORDER TO DEVELOP MAXIMUM COORDINATION OF FIRE CONTROL EFFORT.

TACTICAL USE OF AIR TANKERS ON FIRES:

1. AIR TANKERS SHOULD BE USED THE SAME AS ANY OTHER FIRE TOOL, WITH ESSENTIALLY THE SAME STRATEGY AND TACTICS.

2. RETARDANT LINES SHOULD BE LOCATED IN MUCH THE SAME PLACES AS ANY OTHER TYPE OF CONSTRUCTED LINE: AT THE HEAD OF THE FIRE IF ITS BEHAVIOR INDICATES SUCH ACTION IS LIKELY TO BE SUCCESSFUL, ON THE FLANKS IF HEAD ACTION CANNOT BE SUCCESSFUL, IN AN INDIRECT LOCATION IF A DIRECT LINE IS LIKELY TO BE OUT-FLANKED, IN THE LIGHTER FUELS, TAKING ADVANTAGE OF NATURAL BARRIERS, ETC.

3. AIR TANKERS SHOULD ATTEMPT TO ENTIRELY CONTAIN A SMALL FIRE, IF THEY CAN. IF THEY CANNOT ENTIRELY SURROUND THE FIRE WITH THEIR FIRST SERIES OF DROPS AND NO GROUND FORCES ARE AVAILABLE FOR FOLLOW-UP, THEY MAY BE MOST SUCCESSFUL IN FLANKING ACTION, EVEN ON SMALL FIRES.

4. ON LARGE FIRES AIR TANKERS ARE MOST EFFECTIVELY USED IN HOT-SPOTTING, ON SPOT FIRES, IN FLANKING ACTION, AND IN PRETREATMENT WORK IN THOSE INSTANCES WHERE SUCH ACTION CANNOT BE DONE AS WELL BY GROUND FIREFIGHTING UNITS.

5. ON FAST MOVING FIRES AIR TANKERS ARE MORE OFTEN SUCCESSFUL ON FLANKING ACTION TIED TO AN ESTABLISHED FIREBREAK. A NOTABLE EXCEPTION IS WHEN THE FAST MOVING FIRE HAS A VERY NARROW FRONT WHICH MAY BE STOPPED BY ONE OR TWO DROPS.

6. Hot fires running swiftly up a steep slope in heavy fuels can be attacked most successfully by air tankers by pretreating ridges or benches where fire spread will slow or lighter fuels which are more easily held by a given drop of retardant.

7. On high intensity fires larger air tanker types or the overlapping of drops by smaller types may be desirable.

8. A sustained air tanker operation requires careful and timely planning for relief of pilots, occasional maintenance of aircraft, additional supplies of gasoline and oil for aircraft, additional retardant supplies, possible relief of airport personnel, etc.

9. Air tankers should rarely be used in mop-up action.

Drop techniques:

1. Each pilot should know the height and speed which will provide the optimum drop pattern from his tanker.

2. Drops from tankers presently specified in contracts by California firefighting agencies should not be made from altitudes below 50 feet because of the danger to ground personnel, possible damage to equipment, the possibility of the prop wash fanning the fire into greater activity, and the waste of retardant.

3. Pilots should be trained to judge drop heights.

4. Drops should not be made at right angles to the fireline if they can be avoided.

5. For safety of operation and for a more effective retardant pattern on the ground, air tankers should drop into the wind when winds are above 20 miles per hour.

Safety:

1. Steep topography, dense smoke, high timber and snags, shifting and high velocity winds, and turbulent air are all flying hazards and may restrict or exclude air tanker use.

2. Thunderclouds indicate the presence of dangerous down drafts.

3. High telephone and power lines on a fire should be reported to incoming air tankers.

4. Airports having high military or civilian traffic should be informed whenever air tanker action is to take place on a fire near to them.

5. Drops made from an altitude below 50 feet should be avoided because of the potential danger to ground personnel and equipment.

6. Air traffic on a fire must be controlled at all times by one person in command of the operation.

7. Disagreements among air personnel as to tactics must be avoided during fire action; they can be discussed at a later critique.

Retardants:

1. Care should be taken to be sure that all retardants are properly mixed.

2. With our present knowledge, high viscosity appears to be a very desirable characteristic in any retardant slurry. It is especially important in a good bentonite slurry.

3. The drop characteristics of well-mixed borate and bentonite are about the same under all conditions.

4. Increasing the height and speed of an air tanker will increase the drift of any retardant dropped, which may be desirable on light fuels and fires of low heat intensity.

5. Bentonite and borate appear to be equally effective in retarding fire spread when dropped relatively near to the fireline. The lower cost of bentonite should be considered in selecting the retardant to be used.

6. If the fireline probably will not reach the drop line within one and a half to two hours, then borate should be used rather than bentonite.

Future studies to improve the use of air tankers and fire retardants include continued evaluation of air tanker use on forest fires; the study of additional fire retardants such as a vermiculite-bentonite mixture, ammonium phosphate, viscous water with and without added chemicals, and bentonite foam; tests to determine the impact forces of retardant drops on ground personnel; studies of different retardant mixers; the determination of retardant characteristics important for penetration of dense vegetative canopies; and the study of retardant concentrations needed for different fuel types under different burning conditions.

DESCRIPTION OF PROJECT

Objectives

1958 air tanker activities provided valuable information in certain specific areas (11), but there appeared to be too many gaps in the available data to permit air tankers to be placed in proper perspective with other firefighting forces. These additional needs were reflected in the following objectives for the 1959 program:

1) Examine the effectiveness of several air tanker types in relation to various fire situations, especially when used for initial attack.

2) Establish guidelines for developing local dispatch and tactical use criteria for initial attack and follow-up fires.

3) Study abilities of pilots and aircraft to perform effectively in dropping retardant chemicals on forest fires.

4) Study methods of integrating air and ground forces for initial attack operations.

5) Study economics of air tanker use.

<u>Standards established to minimize variables</u>

In order to accomplish these objectives it was imperative that the variability of various factors be stabilized or minimized as much as possible. The following procedures were initiated or strengthened after 1958 experiences:

1) Equipment standards

In 1958 there was considerable variability noted in tank and gate designs. It was found that certain tank designs with protruding lips, flanges or other areas of entrapment caused the chemical to break up too quickly or to string out beyond the target. Only that equipment which would produce a clean, quickly expelled drop was acceptable. Generally speaking, this meant that gates were as large as the tank bottom would permit with no obstructions to the flow of the retardant.

2) Retardant standards

With the use of bentonite as a fire retarding chemical, the need to maintain close control over mixing techniques became increasingly apparent. Thin mixes of either borate or bentonite can produce poor patterns and may be ineffective in retarding fire spread. Bentonite, being most critical in this respect and being influenced by minerals in the water, made it necessary to have close inspection of each mixing operation.

3) Central inspection and direction system

To assure that adequate facilities were established and maintained; that operational problems were not influencing the evaluation; that personnel were properly performing their assigned duties; and that air and ground operations were coordinated, required that an administrative position from the district office be assigned the responsibility of periodically inspecting the forces assigned to the program. Since the evaluation forces were located in more than one ranger administrative unit, it was important to maintain uniformity.

4) Pilot proficiency standards

1958 experience indicated that the variation in pilot abilities

WAS SOMETIMES GREATER THAN THE VARIATION BETWEEN AIRCRAFT TYPES. THIS PROBABLY POSED THE MOST SERIOUS OBSTACLE TO GOOD OBJECTIVE EVALUATION. NEW AIR TANKER PILOTS, EVEN THOSE WITH MANY HOURS OF AGRICULTURAL WORK, ARE OF LIMITED VALUE FOR EVALUATION PURPOSES FOR A CONSIDERABLE TIME. PILOTS WITH NO AGRICULTURAL FLYING MAY REQUIRE 100 OR MORE DROPS ON FIRES BEFORE BECOMING PROFICIENT ENOUGH TO BE DEPENDABLE. OF THE PILOTS USED IN THE 1959 EXPERIMENTAL PROGRAM, ONLY ONE HAD NO PREVIOUS EXPERIENCE AND THE MAJORITY HAD WORKED IN THE 1958 EXPERIMENTAL PROGRAM.

MIXED GROUPS OF UNTRAINED AND EXPERIENCED PILOTS CAN CREATE SERIOUS COMPETITION PROBLEMS. THE EXPERIENCED MAN MAY TRY TO DEMONSTRATE HIS ABILITIES, AND THE UNTRAINED MAN MAY EXCEED HIS EXPERIENCE BY TRYING TO EQUAL THE OTHER'S PERFORMANCE. MIXED TYPES OF AIRCRAFT CAN LIKEWISE RESULT IN COMPETITION TO PROVE ONE TYPE BETTER THAN THE OTHER. SUCH COMPETITION NOT ONLY AFFECTS EVALUATION BUT CREATES A SERIOUS SAFETY PROBLEM.

5) SYSTEM FOR RECORDING EFFECTIVENESS OF DROPS

IT WAS NOTED IN 1958 THAT ANY ONE DROP OBSERVED BY GROUND PERSONNEL COULD BE REPORTED AS EFFECTIVE, PARTIALLY EFFECTIVE, OR INEFFECTIVE, DEPENDING ON HOW EACH INDIVIDUAL SAW IT FROM HIS LOCATION. THE COMPLETE TARGET WAS NOT ALWAYS IN VIEW OF GROUND FORCES DUE TO INTERVENING TOPOGRAPHY OR HEAVY FOLIAGE. IT WAS FOUND THAT MOVIES TAKEN FROM THE AIR, USING THE PROPER TECHNIQUES, COULD PROVIDE A GOOD METHOD OF RECORDING ACTIONS FOR LATER SUBJECTIVE EVALUATION. PHOTOGRAPHERS FOR 1959 WERE GIVEN INSTRUCTIONS BY VIEWING SAMPLE PHOTOGRAPHY SHOWING BOTH GOOD AND BAD TECHNIQUES. IN SPITE OF THIS, SOME OF THE PAST MISTAKES WERE REPEATED UNTIL EACH PHOTOGRAPHER HAD GAINED EXPERIENCE AND HAD REVIEWED SOME OF HIS OWN MOVIES. BEST RESULTS WERE REALIZED WHEN SHOTS WERE TAKEN OF THE TARGET BEFORE A DROP, OF THE DROPS THEMSELVES, AND OF THE FIRE AREA AFTER THE DROP WITH SUFFICIENT FOOTAGE TO STUDY EFFECTS.

REPORTS FROM GROUND FORCES AND AERIAL OBSERVERS WERE MADE ON EACH AIR TANKER OPERATION IN 1959 IN A MANNER SIMILAR TO 1958 (11). THESE PROVIDED THE DATA FOR THE ANALYSIS DESCRIBED ON PAGE 24.

<u>ASSIGNMENT OF AIRCRAFT</u>

IN ORDER TO REDUCE THE VARIABILITY OF DIFFERENT PILOTS AND DIFFERENT AIRCRAFT BEING USED UNDER VARIOUS FIRE SITUATIONS THROUGHOUT THE STATE, AT LEAST HALF OF THE EXPERIMENT WAS DEVELOPED AROUND A TEAM OF FOUR AIR TANKERS. THE TEAM CONSISTING OF THREE N3N'S (200 GALLONS MAXIMUM) AND ONE TWIN BEECH (300 GALLONS MAXIMUM), OPERATED SIX WEEKS IN THE DIVISION'S CENTRAL SIERRA DISTRICT (DISTRICT III), THEN MOVED TO THE NORTH COAST DISTRICT (DISTRICT I) FOR SIX WEEKS, AND FINALLY TO THE SOUTHERN CALIFORNIA DISTRICT (DISTRICT VI) FOR THE REMAINDER OF THE FIRE SEASON (FIGS. 2 AND 3). TWO PHOTOGRAPHERS WERE ASSIGNED TO THE TEAM AND MOVED WITH THEM. TWO "DROPCOS" (DROP COORDINATORS) AND CESSNA 180 OR 182 OBSERVATION TYPE AIRCRAFT WERE ASSIGNED BY EACH DISTRICT IN WHICH THE TEAM OPERATED.

Fig. 2. N3N air tanker, 200 gallons capacity. Three of these aircraft were used in the initial attack experiment.

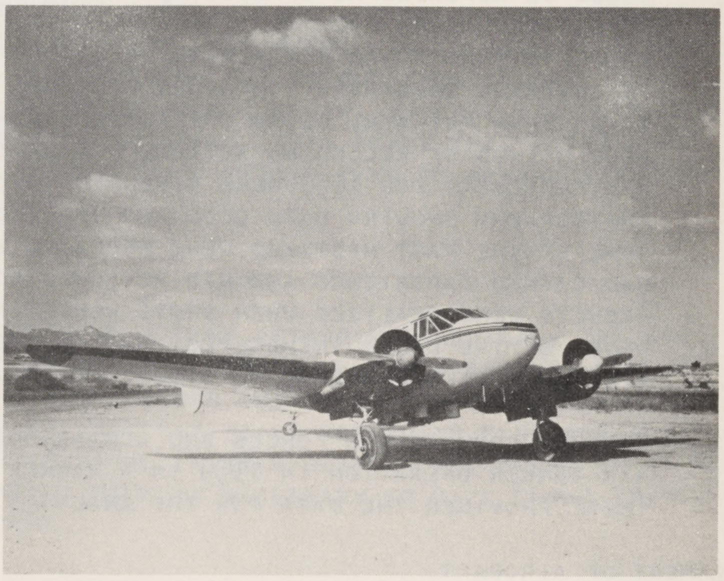

Fig. 3. Twin Beech air tanker, 300 gallons capacity. One plane of this type was used in the initial attack experiment.

In District III the four aircraft were distributed as follows: Loma Rica near Nevada City (later moved to Auburn), three N3N's and one dropco; Columbia, one Twin Beech and one dropco. An additional TBM (600 gallons maximum) at Columbia was part of the experiment, but this ship remained at Columbia for the entire season.

In District I the four aircraft were located as follows: Hoberg's Lake County, two N3N's and one dropco; Ukiah, one N3N, one Twin Beech, and one dropco. No additional air tankers were provided for the periods before arrival or after departure of the team.

In District VI the entire team and one dropco were located at Ryan Field, Riverside County. In addition, one TBM, one F7F (800 gallons maximum), and one dropco were located at Ramona for the entire fire season (figs. 4 and 5). These were also included in the experiment.

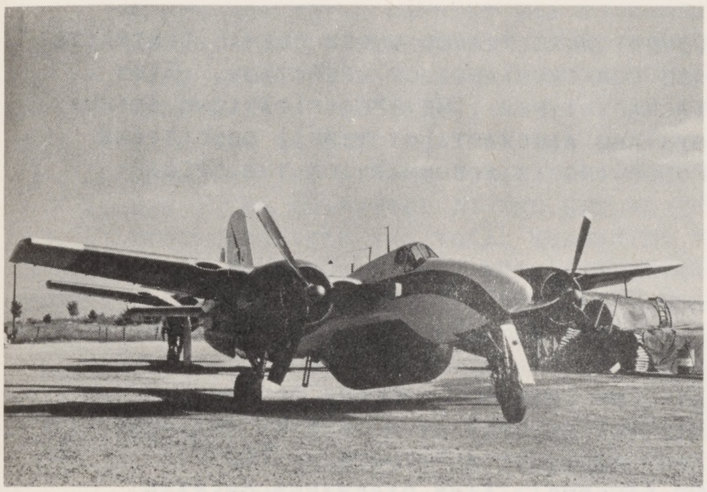

Fig. 4. F7F air tanker, 800 gallons capacity. This aircraft was stationed at Ramona Airport in 1959.

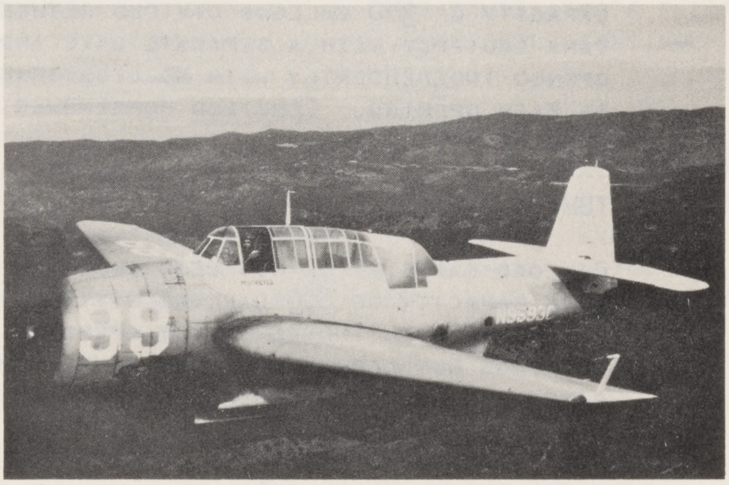

Fig. 5. TBM air tanker, 600 gallons capacity. This type of aircraft was stationed both at Columbia and Ramona Airports in 1959 for the initial attack experiment.

Initial attack definition

For the purposes of the 1959 experiment, definition of "initial attack" was confined to that action which occurred as follows:

1) An air tanker was dispatched before any other firefighting unit, or

2) An air tanker was able to take action on a going fire at least within 15 minutes after the arrival of the first ground crew.

Contracts

All aircraft used in the experiment were placed under formal contracts after competitive bids were solicited for each area of operation. Bids were based on a rate per hour by aircraft type. The specifications stipulated minimum requirements for pilots and aircraft (by type), conditions of use and operating procedures. Following is a summary of the specifications:

1. Aircraft

   a. N3N

   Payload capacity of not less than 180 gallons of fire retardant (at 9.0 pounds per gallon) at a density altitude of 6,300 feet (3,000 foot pressure altitudes at 100°F). Total tank capacity 200 gallons. Tank discharge opening not less than 450 square inches (all N3N's used had 500 square inch openings). Engine horsepower not less than 600. Equipped with an electric starter.

   b. Twin Beech

   Payload capacity of not less than 300 gallons with total capacity of 380 gallons divided between two tanks. Each tank equipped with a separate gate and capable of being opened independently with no less than 600 square inches in each opening. Combined horsepower of both engines not less than 900.

   c. TBM

   Payload capacity of not less than 500 gallons and total tank capacity of 600 gallons divided into two equal compartments with independently operated gates. Discharge openings not less than 1,000 square inches for each compartment. Engine horsepower not less than 1,900.

   d. F7F

   Payload capacity not less than 750 gallons and total tank capacity of 800 gallons divided into two compartments with independently operated gates. Discharge openings not less than 1,400 square inches for each compartment. Combined horsepower for both engines not less than 4,200.

2. Pilots

Each pilot was required to have a minimum experience of not less than 1,500 hours of flight time, of which not less than 500 hours was in agricultural flying at low elevations, or 200 hours of timber spraying, cargo dropping, air tanker application, seeding, baiting, fish planting, or similar low level mountain flying experience.

3. Payment

A minimum total payment was guaranteed for each aircraft. The amount varied depending on the type of ship and the length of time involved but generally amounted to slightly less than one hour (at the bid rate) per day of the contract period. All flight time was charged against the minimum guarantee. Two methods of applying the minimum guarantee were tried. One method provided the total guarantee at the end of the contract period while the other prorated the total guarantee by weekly periods. It was found that the former method provided the greatest flexibility. The latter method does not allow for "peaking" aircraft use with fire occurrence (except during each weekly period) to take advantage of the total guarantee for actual flight time.

4. General

To be competitive, specifications of contracts were written around aircraft and gate designs which were generally available. There was little opportunity to develop new tank designs or gate release mechanisms except as was done voluntarily by the individual operator.

Insurance coverage for aircraft and pilots engaged in this type of work is extremely high and of necessity must be reflected in the rental rate. A serious question arose in 1959 as to the availability of compensation insurance for the contractor's pilot. There is no assurance that compensation insurance will continue to be available in future years.

Although the Division's contracts specified that all necessary maintenance would be performed as stipulated by F.A.A. requirements, the lack of technically trained personnel to periodically inspect the aircraft made it impossible to assure compliance. Even technically trained personnel cannot always determine whether certain engine maintenance has been performed. Here the Division had to rely on the integrity of the operator. Aircraft used in air tanker operations need a level of inspection and maintenance equal to that of commercial airline service.

A rather large investment to an individual contractor is represented in each of these aircraft. The majority are specially designed for fire control work and have no other use. A large number of new operators are continuing to enter this field of activity because of the extensive use of the existing ships during the past few years. Certainly contracts with either the California

Division of Forestry or the U. S. Forest Service are limited to only a small portion of the number of air tankers available. The remainder rely on the occurrence of fires in areas where no contract exists, the development of large fires needing many aircraft or the occurrence of more fires at one time than the contract aircraft can handle.

Under the contract system the Division must negotiate for new contracts each year, and hence there is a possibility of acquiring a completely new group of pilots and aircraft. Although the Division specifies a considerable background of flying time of which a certain portion must be at low level, fire control work is an art in itself. There is no means by which the Division can retain its investment of training and experience without restricting specifications to the point where no competition would exist.

Criteria for standby and dispatching procedure

Air tankers were to be placed on standby when the brush burning index (California Fire Danger Rating System) was predicted for 9 or above. They were also to be held on standby with the brush burning index below 9 when heavy fire activity the previous day had involved a large percent of the normal suppression forces or when a large number of fire starts from lightning or incendiarism had committed most of the other initial attack forces.

Dispatch criteria were aimed at those fires having the greatest potential of becoming C, D, or E size fires (within the limited funds of the experimental program).[2/] It was recommended that maps be prepared for each operating area, eliminating those areas known to consist of dense residential developments, or power and telephone line hazards, or of low resistance to control. It was also recommended that areas of high value, high resistance to control, long travel times for ground crews, and areas which were within 20 minutes travel time from the established airports be delineated on dispatcher's maps. This preparation was done to varying degrees, however, and dispatching actually was influenced greatly by low fire incidence and, consequently, limited opportunities for use in some districts in 1959.

The time for standby to begin on any given day varied from 0800 to 1200 hours, depending on the predicted hazard. The aircraft were to be checked out, warmed up, and the air tankers loaded with retardants prior to the standby time. When a fire was reported on which air tankers were to be used, they were to be dispatched in the same manner as other fire control forces. Dispatch information would include location by section, township, and range, nearest town or landmark, distance, heading in degrees

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2/ Fire size classes: Class A fire - .25 acres, or less; Class B fire - .26 through 9 acres; Class C fire - 10 through 99 acres; Class D fire - 100 through 299 acres; Class E fire - 300 or more acres.

from airport, and elevation of the fire. Dropcos were to respond with the air tankers and maintain radio contact for coordination with ground forces.

Operating procedures

When air tankers arrived at a fire prior to ground forces and the dropco, they took independent action in accordance with prior fire control training (see section on Training). Otherwise the dropco assumed the responsibility for selecting targets or coordinating drops with the requirements of ground forces. Once the ground forces arrived, the fire boss "called the shots" for air tanker activity through the dropco. It was not unusual, however, because of his overall view of the fire, for the dropco to suggest the appropriate action to the fire boss.

Since dropcos were not normally pilots nor familiar with the limitations and performance characteristics of air tankers, they did not attempt to lead the air tankers into the target nor to tell the pilots how to make their drops. On the initial action the dropco might make a low level pass over the fire area and would then inform pilots of hazards, air turbulence, or other pertinent information. Otherwise the dropco maintained an orbit at 1,000 feet above the area and coordinated the orbiting, approach and departure of the air tankers. The extent of direction from the dropco with regard to the drop itself was confined to identifying the target and indicating when the drop was to be made. The manner in which the drop was made was left to the pilot; final decision on whether the drop could be safely made was also left to the pilot.

PROJECT MANAGEMENT

Although aircraft, pilots, and personnel were assigned to specific bases and were dispatched by a ranger unit dispatcher, the striking range of the air tankers was not confined to any single administrative unit. Three or more ranger units were within one-half hour flight time from each base of operations.

In order to have continuity and consistency of use it was necessary to establish a direct administrative contact from the district headquarters to the project personnel. This responsibility was assigned in each case to the district fire control ranger.[3/] This procedure posed problems of coordination at times since normal administrative channels through the ranger units were being by-passed. Every effort was made to keep local fire control personnel informed, however.

Likewise, since the project was a statewide experiment, close liaison was necessary from the Division's fire control headquarters in Sacramento. The ranger unit in which an air base was located was responsible for providing equipment and personnel to operate the base and coordinating the day-to-day business within the guidelines established by Division and district headquarters. The 1959 project differed from 1958 in that the district fire control ranger acted as project leader for the forces in his district. A separate assigned project leader was used in 1958 in each district.

3/ Fire control staff officer at each district headquarters.

One dropco was located at each base. This position was filled (with one exception) by forest firefighter foremen in 1959. Foremen, assistant rangers, and associate rangers were used in 1958. The dropco was in charge of the base and was responsible for supervising support activities. He inspected daily the mixing and storage facilities and made checks to determine that pilots and aircraft were in compliance with contract terms. When airborne, he was responsible for coordinating air tanker activity with the requirements of ground forces.

One forest firefighter was assigned to each base to act as timekeeper, to assist with loading operations, and to operate base communication systems. Crews consisting of three firefighters, one driver, and the dropco were permanently stationed at two of the larger bases (Ryan and Ramona). Mixing was usually done with Conservation Camp or California Division of Forestry crews.

RECOMMENDATIONS FOR FACILITIES

Airport facilities for the 1959 operations varied in adequacy from good to bad, with much to be desired at some locations in the way of both equipment and arrangement (fig. 6). Much of the inadequacy was due to the short notice with which the experiment was launched. Funds had to be taken from other budgeted programs, equipment had to be obtained wherever it might be immediately available (most pumps and storage tanks were obtained from federal surplus supplies), personnel to man the program had to be taken from the regular fire control forces and therefore were, of necessity, limited both in number and in training in air operation procedures. Adequate personnel and facilities, properly arranged, can provide the key to decreasing the down-time of aircraft on a sustained

Fig. 6. Mixing facilities were inadequate at some air tanker bases in 1959.

FIRE CONTROL OPERATION. THE FOLLOWING ARE RECOMMENDATIONS FOR MINIMUM FACILITIES FOR PERMANENT AIR TANKER BASES:

STORAGE

TANKS FOR BOTH BENTONITE AND BORATE SHOULD BE PROVIDED WITH A TOTAL CAPACITY OF NOT LESS THAN 10,000 GALLONS WHERE SMALL AIR TANKERS ARE USED AND 30,000 GALLONS WHERE LARGER AIR TANKERS ARE USED. IN ANY EVENT, THERE SHOULD BE A SUFFICIENT BACKLOG OF CHEMICAL FOR A SUSTAINED OPERATION OF AT LEAST FOUR HOURS WITHOUT ADDITIONAL MIXING OF RETARDANT.

LOADING AND MIXING FACILITIES

A TRANSFER PUMP CAPABLE OF DELIVERING 500 GALLONS PER MINUTE IS DESIRABLE AT ALL LOCATIONS WITH THE POSSIBLE EXCEPTION OF THOSE BASES WHERE ONLY SMALL AIRCRAFT CAN BE USED. EXPERIENCE HAS SHOWN THAT A MAJOR PORTION OF THE DOWN-TIME IS CONSUMED BY LOADING. TWO $2\frac{1}{2}$" LOADING HOSES SHOULD BE PROVIDED AND ARRANGED SO THAT TWO AIRCRAFT MAY BE LOADED SIMULTANEOUSLY OR SO THAT BOTH HOSES CAN BE USED TO FILL ONE LARGE AIRCRAFT. TWO ALTERNATE SMALLER TRANSFER PUMPS SHOULD BE ON HAND TO USE IN EVENT OF FAILURE OF THE PRIMARY PUMP. ONE PRESSURE PUMP CAPABLE OF PRODUCING 100 GPM WILL BE NEEDED WHEN INJECTOR TYPE MIXERS ARE USED TO MIX RETARDANT SLURRIES.

THE MIXING AND LOADING AREAS SHOULD BE LOCATED SEPARATELY SO THAT BOTH OPERATIONS MAY BE CONDUCTED SIMULTANEOUSLY. ADEQUATE DRAINAGE SHOULD BE PROVIDED AT BOTH AREAS SO THAT RETARDANT SPILLAGE MAY BE WASHED AWAY WITHOUT AFFECTING OTHER AIRPORT FACILITIES. WATER UNDER PRESSURE SHOULD BE AVAILABLE FOR WASHING AIRCRAFT. LOADING AREAS SHOULD BE PAVED OR COATED TO ELIMINATE THE DUST PROBLEM RESULTING FROM PROPELLER BLAST AND TO FACILITATE REMOVAL OF SPILLED RETARDANTS.

A BATCH TYPE MIXER FOR BENTONITE WILL UNDOUBTEDLY PROVE TO BE MOST EFFECTIVE AND RELIABLE FOR LARGE, PERMANENT BASES. A PORTABLE INJECTOR TYPE MIXER SHOULD BE ON HAND AS AN ALTERNATE AT PERMANENT BASES AND WILL BE ADEQUATE FOR MOST TEMPORARY BASES.

A WAREHOUSE OF SOME SORT IS RECOMMENDED FOR DRY CHEMICAL STORAGE. SUFFICIENT SPACE SHOULD BE PROVIDED FOR A SEASON'S SUPPLY OF MATERIAL. A SKIPLOADER IS RECOMMENDED FOR TRANSPORT OF PALLETED SACKS OF DRY RETARDANT MATERIAL.

FUELING FACILITIES

STORAGE OF AIRCRAFT FUEL SHOULD BE ADJACENT TO BUT SHOULD IN NO WAY INTERFERE WITH THE CHEMICAL STORAGE AND LOADING AREA. CONSIDERATION SHOULD BE GIVEN TO PROVIDING HIGH TEST FUEL FOR CERTAIN AIRCRAFT TYPES AND ALSO TO BEING CERTAIN THAT ALL FUEL IS FRESH AND UNCONTAMINATED BY WATER OR RUSTED PARTICLES FROM THE INTERIOR OF THE FUEL STORAGE TANK.

BRIEFING AND DISPATCHING ROOM

EXPERIENCE HAS SHOWN THAT A ROOM, SMALL BUILDING OR TRAILER WITH FACILITIES FOR DESK WORK IS HIGHLY DESIRABLE. A DISPATCH MAP SHOULD BE PROVIDED WITH A COMPASS RING AROUND THE AIRPORT LOCATION, ORIENTED SO THAT MAGNETIC COMPASS DIRECTIONS CAN BE PROVIDED TO THE PILOTS.

Lounging and recreation facilities

There are many hours and days when air tankers on initial attack standby will not be used because of no fire occurrence. Lounging and recreation facilities should be provided for pilots during these periods. Waiting for fire action can become exceedingly boring if no mental and physical outlets are available.

Airports

Only those airports should be used which have been approved for the type of aircraft being utilized. Through a cooperative program with the U. S. Forest Service, all available fields in California have been categorized into classes. Many have been ruled out because of inadequacies, location, volume of air traffic, etc. Because of the additional hazards which an air tanker operation places on any airport, it is essential that every effort be made to conduct the operation with a reasonable margin of safety. Close cooperation with airport management should be initiated so that there will be as little interference as possible with regular activity. Pilots must be cautioned to observe all normal procedures concerned with approach, landing, taxi, and take-off.

RECOMMENDATIONS FOR TRAINING

As in all other aspects of fire control operations, complete training of all personnel involved in the air tanker program is essential for effective, economic, and safe operations. All personnel should receive basic training in at least the following subjects:

1. Objectives of the program
2. General organization and responsibilities of personnel concerned with the total program
3. Air tanker organization: air base facilities, initial attack, sustained operation
4. Dispatching procedures
5. Forms and records
6. Communications
7. Safety in all phases of the operation

In addition specific groups of personnel should receive other specialized training, as follows:

Pilots

Pilots must be trained most particularly in safe and effective operations while in action on or near a forest fire. Knowledge of their working relationships with other fire control personnel is also necessary.

Training should include at least one formal session near the beginning of each fire season to acquaint or reacquaint pilots with all phases of fire control organization and tactics. Less formal sessions should be conducted on a continuing basis throughout the fire season to review important points and to gradually increase the level of knowledge of the pilots.

Critiques should be held following every fire action, if at all possible. The critique should include the pilots and drop coordinators from all air tanker bases involved in the fire action and personnel who were engaged in fighting the fire from the ground. Such critiques are necessary and helpful in smoothing out coordination between ground and air forces and in correcting mistakes inadvertently made either by the air or the ground forces because of a lack of knowledge, training, or understanding.

The formal training session near the beginning of the fire season may vary in content according to the experience of the individual pilots but probably should include at least the following items in addition to the basic training:

1. Fire behavior principles
2. Agreement terms and conditions
3. Aircraft and pilot standards
4. Flight and drop techniques, including knowledge of optimum drop patterns and estimation of height above the vegetation
5. Aerial tactics on fires
6. Coordination with ground forces, with other aircraft and with other firefighting agencies

<u>Drop coordinators</u>

Since the drop coordinator is presumed to be an experienced fire control man, his training will be principally along the lines of supervising the air tanker unit at the airport and in action on forest fires and of coordinating the air forces with the ground forces. Basic training should be supplemented by all subjects included in pilot training and also the following items:

1. Direction of pilots on the ground and in the air
2. Fiscal aspects of the program
3. Characteristics of fire retardants and their effect on fire behavior
4. Principles of flight and limitations of aircraft
5. Flight weather
6. Capacities and flight characteristics of different air tankers
7. Recognition of special topographic, weather, or improvement hazards which could affect the safety of the air operation

<u>Airport personnel</u>

Facilitating and servicing personnel will normally be available at the air base to mix and load fire retardant slurries, to maintain facilities, and occasionally to dispatch and to maintain office records. These people should be trained in basic subjects and the following additional subjects:

1. Working knowledge of different types of retardants
2. Mixing, storing, and loading operations
3. Characteristics of aircraft while on the ground
4. Servicing of aircraft with fuel and oil

Fire managers

It is especially important for fire managers to be thoroughly acquainted with all aspects of the air tanker program and to know how, when, and where to integrate the air tanker with all other fire tools available for a specific fire. He is responsible more than any other one person for deciding when air tankers should be requested for use on a going forest fire, where and how they can most effectively help suppress the fire, and when their use should be terminated, either for reasons of economy or because they have performed all the work for which they are better suited than any other fire tool.

These same principles apply, of course, to the use of any other type of fire tool, and herein lies the secret of efficient management of the air tanker as a fire tool: it should be used the same as any other tool, in much the same places, in much the same manner, and with much the same strategy and tactics. The air tanker is not a super-tool but is capable of performing certain tasks in a superior and economic manner. It is therefore essential that all fire managers who are potential users of air tankers be thoroughly acquainted and trained in the air attack program. A training program for fire managers should include at least the following subjects in addition to basic training:

1. Flight and drop characteristics of air tankers
2. Capacities of different air tankers
3. Aerial tactics on fires
4. Coordination of ground and air forces; maintenance of contact with drop coordinator or a lead pilot
5. Necessity of communicating to the air forces the location of special ground hazards, such as high power and telephone lines, individual tall snags or trees, etc., so they may be noted specially by the pilots and avoided
6. Alerting ground personnel to use of air tankers on the fire
7. Characteristics of fire retardants and their effect on fire behavior
8. Fiscal aspects of the program

Fire crews

Fire crews must be trained principally in safety aspects and in follow-up action after a drop has been made on a fire from an air tanker. Safety will include knowing what evasive action to take when in the immediate target area and what care is needed when hiking and working in an area where a drop of bentonite or viscous water has already been made (these retardants are particularly slippery). Crew leaders may often assume the role of fire managers and will require training in the responsibilities of that particular fire job. Training for fire crews should include basic subjects and at least the following additional items:

1. Flight and drop characteristics of air tankers
2. Necessity of communicating special ground hazards to air forces
3. Follow-up tactics after a drop has been made
4. Characteristics of fire retardants and their effect on fire behavior

DISPATCHERS

RANGER UNIT DISPATCHERS ARE PRINCIPALLY CONCERNED WITH KNOWING WHEN AIR TANKERS SHOULD BE DISPATCHED ON INITIAL ATTACK. THEIR DECISIONS WILL BE BASED ON CONSIDERABLE PRE-FIRE PLANNING, INCLUDING THE POSSIBLE CONSTRUCTION OF AN AIR OPERATIONS MAP, WHICH IS DISCUSSED IN MORE DETAIL IN THE NEXT SECTION OF THIS REPORT, "USE OF AIR TANKERS ON FOREST FIRES."

DISPATCHERS WOULD NOT BE PARTICULARLY CONCERNED WITH PRINCIPLES INVOLVED IN DISPATCHING AIR TANKERS ON FOLLOW-UP ACTION SINCE SUCH DISPATCHING WILL BE REQUESTED BY THE FIRE MANAGER BASED UPON HIS OWN EXPERIENCE AND TRAINING AND KNOWLEDGE OF THE FIRE SITUATION. DISPATCHERS SHOULD BE THOROUGHLY TRAINED IN AT LEAST THE FOLLOWING SPECIALIZED SUBJECTS IN ADDITION TO BASIC TRAINING:

1. CAPACITIES AND FLIGHT CHARACTERISTICS OF DIFFERENT AIR TANKERS
2. PRINCIPLES OF PRE-FIRE PLANNING AN AIR ATTACK ORGANIZATION; INTEGRATION WITH EXISTING FIRE CONTROL ORGANIZATION
3. PRINCIPLES OF DISPATCHING AIR TANKERS ON INITIAL ATTACK
4. STRATEGICAL AND TACTICAL USE OF AIR TANKERS ON FOREST FIRES AND THEIR RELATIVE MERITS COMPARED TO OTHER FIRE TOOLS
5. RECOGNITION OF SPECIAL TOPOGRAPHIC, WEATHER, OR IMPROVEMENT HAZARDS WHICH COULD AFFECT THE SAFETY OF AN AIR OPERATION
6. NEED OF NOTIFYING ALL NEARBY AIRPORTS, CIVIL AND MILITARY, WHENEVER AIR ATTACK IS TAKING PLACE ON A FOREST FIRE; ALL AIRCRAFT NOT DIRECTLY CONCERNED WITH ACTION ON THE FIRE MUST BE WARNED TO REMAIN AWAY FROM THE FIRE AND BE ALERT TO AIR TANKERS FLYING AT RELATIVELY LOW ALTITUDES TO AND FROM THE FIRE AND THE BASE AIRPORT
7. AGREEMENT TERMS AND CONDITIONS

AIR PROGRAM ADMINISTRATORS

UNIT ADMINISTRATORS WHO MAY ONLY RARELY BE DIRECTLY CONCERNED WITH THE ACTION AND USE OF AIR TANKERS ON FOREST FIRES WILL OFTEN BE DIRECTLY CONCERNED WITH THE FISCAL ASPECTS AND WITH THE GENERAL PLANNING, DIRECTING, AND SUCCESSFUL CONDUCTING OF THE PROGRAM. SINCE THEY ARE PRIMARILY RESPONSIBLE FOR THE ENTIRE PROGRAM, INCLUDING TRAINING, THEY SHOULD BE ACQUAINTED IN GENERAL WITH ALL SUBJECTS TAUGHT TO ALL PERSONNEL.

USE OF AIR TANKERS ON FOREST FIRES

HOW THE ANALYSIS WAS MADE

ONE OF THE OBJECTIVES OF THE DIVISION'S 1959 AIR TANKER INITIAL ATTACK EXPERIMENT, AS HAS BEEN STATED, WAS TO ATTEMPT TO REFINE ITS INITIAL ATTACK DISPATCHING AND TACTICAL USE GUIDELINES. THIS WAS ACCOMPLISHED PARTIALLY BY AN ANALYSIS OF BOTH SUBJECTIVE AND OBJECTIVE DATA FROM THE REPORTS WRITTEN BY FIELD FIRE CONTROL PERSONNEL AND FROM THE SEVERAL THOUSAND FEET OF 16 MM MOTION PICTURE FILM. THE OVERALL USE OF AIR TANKERS ON ANY ONE FIRE WAS SUBJECTIVELY JUDGED TO BE "EFFECTIVE", "INEFFECTIVE", OR "NOT NEEDED." BECAUSE OF THE MANY CONTRIBUTING FACTORS, THERE WAS NO SHARP DEFINITION OF THE ABOVE TERMS OF EFFECTIVENESS. THE SUBJECTIVE JUDGMENTS WERE BASED ON SUCH TYPICAL ITEMS AS WHETHER OR NOT

1) Ground crews were making effective action on the fire prior to the arrival of the air tankers,
2) The air tankers permitted ineffective crew action to become effective,
3) The air tankers retarded fire spread, cooled hot spots, or checked spot fires,
4) The final size of the fire was reduced by the use of air tankers,
5) Burning conditions were such that ground crews could have readily controlled the fire regardless of air tanker use.

The degree of effectiveness of the air tankers was reduced to several categories in a further attempt to discover clues that would contribute to refinement of use guidelines. Figure 7 shows the categories into which each fire was placed; the number of fires placed in each category by the analysis is noted in parentheses. Categories 3 and 6 are arbitrary by the definition of initial attack used in the analysis (page 12). Air tankers were judged as ineffective on initial attack and placed in categories 5A or 5B, and thence in categories 5C or 3 or 6, if the fire was not controlled by the time of final action of the air tankers on the first day.

Clues as to why specific air tanker actions fitted into the various categories were obtained by studying the mass of data recorded throughout the experiment. Relative effectiveness or need of air tankers was compared to at least the following factors on all fires:

1. Burning Index
2. Air temperature
3. Relative humidity
4. Wind speed
5. Topography
6. Vegetative type
7. Rate of spread of fire
8. Crew getaway and travel time
9. Air tanker getaway and travel time
10. Distance to fire (crews and air tankers)
11. Time of day
12. Size of fire at time of attack by air tankers
13. Increase in size of fire during air tanker action
14. Retarding of fire by individual drops from tankers
15. Degree of effectiveness of crew action

Another objective of the 1959 air tanker program was to study the overall effectiveness of air tankers in relation to various fire situations, especially when used in initial attack, and to study the economics of air tanker use. One criterion used to meet this objective was to study the size of fires when first attacked and their final size at time of control. This relationship was compared between those fires on which air tankers were used in initial attack and all fires attacked by the Division's forces in 1959. While such a comparison of just one year's data cannot be considered as being statistically significant, it can provide tentative conclusions which may be of temporary value and which must be supported by subsequent years' data.

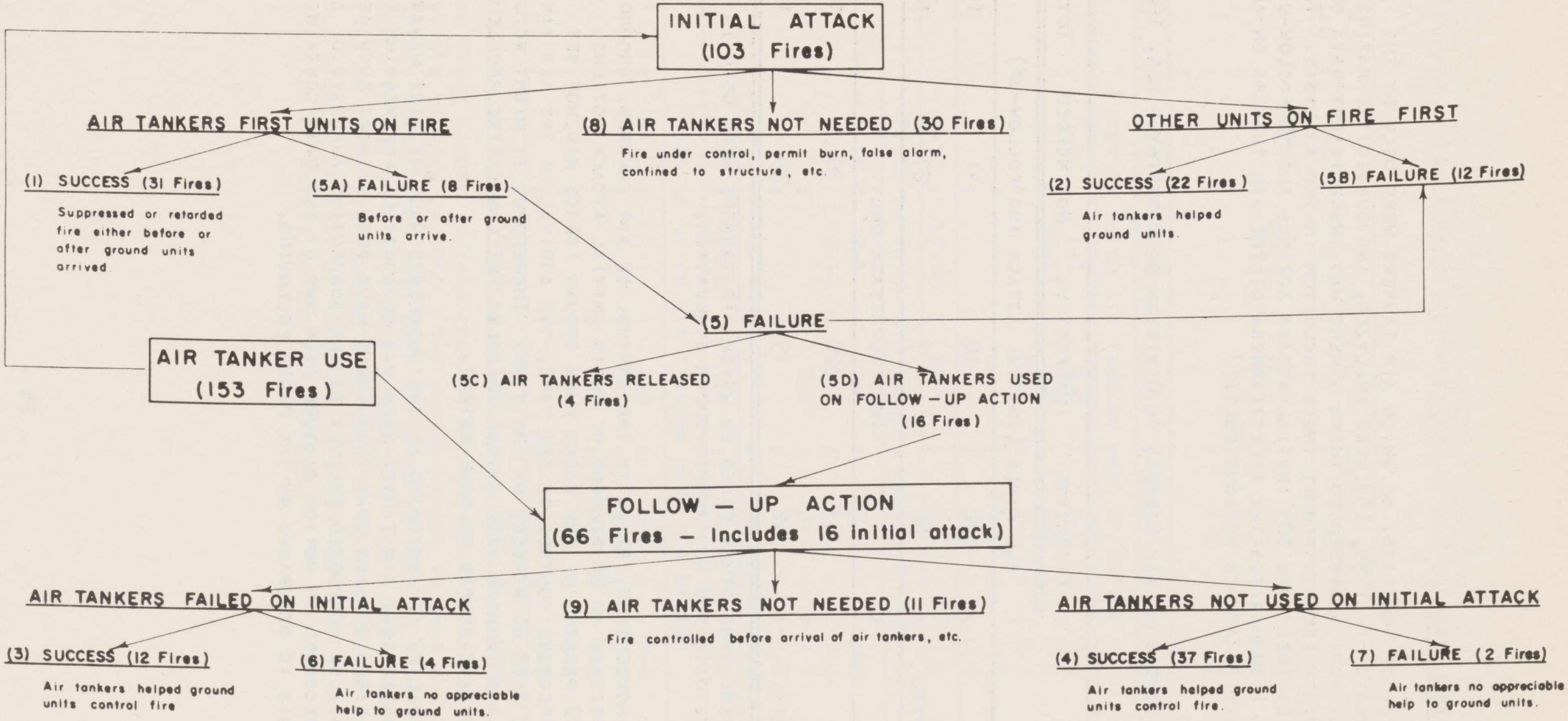

FIG. 7 CLASSIFICATION OF AIR TANKER EFFECTIVENESS ON FOREST FIRES IN 1959

Results of the analysis

Of the total of 162 fires on which air tankers were used by the Division of Forestry in 1959, 153 were analyzed, and subjective ratings of effectiveness were assigned to them. There was insufficient data on the remaining nine fires to permit their inclusion in the analysis. The 153 fires were divided into 103 initial attack actions and 50 follow-up actions. Table 1 summarizes the effectiveness of the air tankers on all fires and in initial attack actions only.

Table 1. Effectiveness of air tankers on Division of Forestry fires, 1959.[A/]

	Effective	Ineffective	Not needed	Total
	All fires (initial attack and follow-up)			
Number of fires	102	10	41	153
Percent of total	66	7	27	100
	Initial attack only			
Number of fires	53	20	30	103
Percent of total	52	19	29	100

A/ There were nine other fires on which air tankers were used in 1959 but insufficient data did not permit their evaluation.

The data showed that, prior to the arrival of air tankers, ground forces were effective in 28 percent of their initial attack actions. Of the remaining 72 percent of the cases when ground forces had not yet attained any effective control of the fire, the arrival of the air tankers helped turn the tide 61 percent of the time. Therefore, it might be said that while the air tankers have failed to solve the large fire problem in all cases, they have helped to some extent.

This possibility is supported by the judgments made by fire managers when they estimated that air tanker help was responsible for keeping 41 percent of the fires smaller than they would have been without such help. This opinion is also supported vividly by the subjective analysis of air tanker action recorded on motion picture film and by the data contained in Table 2. This is described on the pages following.

Table 2. Number of fires initially attacked by air tankers, by size class.[a]

Fire size at first attack	Final size of fire: A	B	C	D	E	Total
A	10-42	3-3	0-0	0-0	0-0	13-45
B		32-37	12-5	11-0	7-0	62-42
C			13-6	3-3	4-2	20-11
D				1-0	2-0	3-0
E					0-0	0-0
Total	10-42	35-40	25-11	15-3	13-2	98-98
Fires on which air tankers were effective						
A	5-17	1-1	0-0	0-0	0-0	6-18
B		16-15	5-2	0-0	0-0	21-17
C			10-2	1-1	0-1	11-4
D				0-0	1-0	1-0
E					0-0	0-0
Total	5-17	17-16	15-4	1-1	1-1	39-39
Fires on which air tankers were ineffective						
A	0-15	0-1	0-0	0-0	0-0	0-16
B		2-13	6-2	11-0	7-0	26-15
C			2-2	2-1	4-1	8-4
D				0-0	1-0	1-0
E					0-0	0-0
Total	0-15	2-14	8-4	13-1	12-1	35-35
Fires on which air tankers were not needed						
A	5-10	2-1	0-0	0-0	0-0	7-11
B		14-9	1-1	0-0	0-0	15-10
C			1-2	0-1	0-0	1-3
D				1-0	0-0	1-0
E					0-0	0-0
Total	5-10	16-10	2-3	1-1	0-0	24-24

a/ The first figure in each cell is the number of fires actually attacked by air tankers in 1959. The second figure in each cell is the number of fires which would have been attacked by the air tankers had they conformed to the 1959 statewide averages of all fires. Only 98 of the 103 fires on which air tankers were used in initial attack are included in the table because of lack of information about the size of five of the fires at the time of attack by the air tankers.

Three principal points can be drawn from Table 2, bearing in mind again that one year's data can provide only tentative conclusions which must be supported by additional data from subsequent years' operations:

1. Most fires attacked by air tankers were larger than the statewide average (e.g., only 13 fires were actually attacked at size class A whereas the number should have been 45 according to statewide averages; on the other hand, 62 fires were attacked at class B and 20 at class C, whereas the numbers should have been only 42 and 11, according to statewide averages).

2. Considering fires on which air tankers were judged to be effective, the number which became size class D or E was no greater than should have been expected by the statewide average (e.g., only one fire escaped into size class D and one into size class E after effective attack by air tankers, which agreed with the number of fires expected by the statewide averages).

3. Considering fires on which air tankers were judged to be ineffective, the number which became size class D or E was considerably greater than should have been expected by the statewide average (e.g., 13 fires escaped into class D and 12 into class E, whereas only one fire should have been expected in each class according to the statewide averages).

The obvious conclusion is, of course, that air tanker use should be made effective as often as possible in order to reduce fire size and hence fire damage plus suppression costs. Such effectiveness can be attained only through careful planning of the air tanker program, continued evaluation of air tanker action, and proper training of all personnel involved in the program.

There are several reasons why Table 2 shows fires initially attacked by air tankers as being larger than the statewide average: (1) the air tankers were used only for a part of the fire season and generally were not used on early season or late season fires which tend to be small on first attack and to remain small; (2) the air tankers were placed on standby only when the Burning Index was 9 or above and consequently the statewide averages include many small fires which started during periods of poor burning conditions and which tended to remain small; (3) the air tankers normally were not dispatched to fires which could be reached quickly by ground forces, again resulting in additional small fires which tended to remain small; (4) the air tankers were almost always dispatched to isolated fires which tended to be large upon their arrival and which therefore tended to burn into the next size class more readily than fires which were smaller upon initial attack. Therefore it can probably be generalized that air tankers, under present guidelines of use, will always reach fires on initial attack which will tend to be larger and more intense in heat energy output and which will tend to become larger during attack action than the "average" fire attacked by ground forces statewide. This generalization makes more important than ever the quick dispatching of air tankers when they are actually needed.

The analysis of the 103 fires on which air tankers were used in initial attack and the assignments of those fire actions to effectiveness classes according to figure 7 was completed long before the statewide averages had been computed by the Division's statistical section. Therefore the data in Table 2 were used merely as a check against the subjective judgments of air tanker effectiveness that had already been made on the basis of various other factors. The fact that Table 2 supported so well the general classifications already made merely served to strengthen the original decisions.

A better statistical comparison between actual fires attacked by air tankers and the statewide averages can be made by extracting from the statewide data only those fires which occur under the same general conditions as the fires attacked by air tankers. That is, fires could be extracted which occurred only on the exact days when the air tankers were on active standby and which occurred only in those areas where air tankers could be expected to be used if they were available. Unfortunately, time did not permit this extraction of data from the statewide totals for this report, but it will be done sometime in the near future and for any other annual reports that may be published by the Division on its air tanker operations.

In several instances when air tankers were dispatched as a precaution because burning conditions favored fire spread or because a fire was isolated, they were not needed upon arrival because the fire was either under control, being readily controlled, or could easily have been controlled by forces arriving soon. In a few cases the fires were started by lightning from wet storms and were confined to snags or spots. Occasionally air tankers were dispatched to false alarms. If air tankers are to be dispatched quickly on initial attack, there will always be those occasions when they will not be needed; this same situation exists in the initial attack dispatching of ground units. The number of such occasions can be minimized, however.

While one year's data cannot be construed as being concrete evidence, analysis of the 1959 air tanker program did help to support tentative guidelines used by fire administrators in the past and also pointed out a few new areas for strong consideration. Only through continued and long-term evaluation of its air tanker program can the Division hope to refine even further its use guidelines and to determine on a statistical basis the conditions under which air tankers should be used and the manner in which they should be used in order to help reduce overall fire costs. The following points seemed to be most strongly evident from analysis of the 1959 air tanker program data.

- Planning an air tanker program -

1. Type of air tanker to use:

   The choice of which type or types of air tankers to use often will be dictated wholly by availability of aircraft or by available funds. If a choice is possible, several factors should be considered:

   a) Distances between available airports. The data indicated that the optimum distance between airports for smaller air tankers (300 gallon capacity or less) is 40 to 60 miles; for larger air tankers, 60 to 80 miles may be permissible.

b) Topography. Where the terrain is cut generally by a large number of deep, narrow canyons, air tankers most maneuverable, such as the N3N, are desirable.

c) Fire behavior. When fire behavior is commonly extreme with high heat intensity and a fast rate of spread in heavy fuels, air tankers with larger load capacities (600 gallons or more) are desirable.

d) Air tanker capability. Air tanker types vary considerably in their capability to deliver retardant to a fire. All other things being equal, the larger, faster air tanker will always deliver more retardant per unit time than the smaller, slower tanker. This general statement, however, does not take into account those factors which tend to make an individual drop effective: pilot ability, tank and gate configuration, maneuverability of the aircraft at the scene of the fire, etc. These factors are extremely important and must be weighed in judging the overall capabilities of air tankers under consideration for use.

Disregarding effectiveness of individual drops, the data from the Division's 1959 operations showing the performances by different air tanker types averaged over all fires are summarized in Table 3.

Table 3. Performance of air tankers on Division of Forestry fires, 1959

Tanker Type	Capacity (Gals.)	Average Speed[A/] (MPH)	Average Down-time[B/] (Mins.)	Avg. Del.[C/] (Gals/Min.)	Gal/Min Ratio[D/]	Contract Rate/Hr	Contract Rate/Hr[E/] Ratio
N3N	200	90	6	6	1.00	$ 95	1.00
Tw Bch	300	140	9	10	1.67	120	1.26
TBM	600	150	12	18	3.00	220	2.32
F7F	800	180	15	25	4.17	350	3.69

a) Average speed: twice the straight line distance to a fire divided by the total elapsed flight time to and from the fire and averaged over all fire actions. The figures therefore account for time required for taking-off, avoiding topographical hazards in low-level flights to and from the fire, orbiting, maneuvering for drops, landing, etc.

b) Average down-time: measured time between landing and the next take-off on sustained operations, averaged over all such fire actions. The figures account for loading, servicing, maintenance, etc., between trips.

c) Average delivery: total gallons of retardant delivered to a fire over a time measured from first take-off to last landing, including all flight time and all down-time, and averaged over all fire actions.

d) Gallons/minute ratio: the Average Delivery figure for the N3N is arbitrarily set at 1.00; the Average Delivery figures for all other aircraft are compared as a ratio to the N3N. The same procedure can be used to compare the Average Delivery rates of any other pair of aircraft types.

e) Contract rate/hour ratio: again, the contract rate for the N3N is arbitrarily set at 1:00 and the contract rates for other aircraft are compared as a ratio to the N3N.

Actually, the column "Average Delivery, gallons/minute" does not tell a true story since the capability of different air tankers to deliver retardant to a fire varies with volume of load, rate of speed, number of trips to the fire on a sustained operation, distance to the fire from the airport, maneuverability on a fire, and average down-time needed for refilling, servicing, maintenance, etc., between trips. These factors can be combined into a formula which will give the air program administrator one basis for planning his air tanker operation. This formula and its application to the Division's 1959 air tanker operation data are discussed in the Appendix.

2. Air operations map:

Each dispatcher's office should have an air operations map which will contain all the specialized information relative to the use of air tankers and other aircraft on forest fires. Here are some of the things pertinent to air tanker use that should be considered for inclusion:

A. Delineation of areas of use:

1) Certain areas should be delineated where air tanker use normally will be excluded except under extraordinary conditions. Such areas might include those places where historically there have been very few, if any, large fires; zone 3 areas; areas of low value; highly populated areas where historically the local people have contributed to fast initial attack or where the use of low flying aircraft could endanger life and property; areas within 10 minutes travel time of crews (and not influenced by other factors); areas where resistance to control by ground forces is low; deep canyons where no air tanker type can maneuver safely, etc.

2) Other areas should be delineated where air tankers normally will be dispatched on initial attack at all times. Such areas might include high values; high hazards; areas over 20 minutes travel time from crew bases; areas where there is a high resistance to control by ground forces, etc.

3) When fires occur in any area not delineated as "almost never" or "almost always", air tankers should be dispatched on initial attack according to the best judgment of the dispatcher, based upon his knowledge of all factors

CONTRIBUTING TO THE PROBABILITY OF SUCCESSFUL AND EFFICIENT AIR TANKER USE ON FOREST FIRES. THESE FACTORS ARE DISCUSSED UNDER "INITIAL ATTACK DISPATCHING" ON PAGE 31.

B. THE LOCATION OF DEEP, NARROW CANYONS. ONLY THE MORE MANEUVERABLE AIR TANKERS AND MORE EXPERIENCED PILOTS SHOULD BE USED IN SUCH PLACES. SOME CANYONS MAY DICTATE THAT NO AIR TANKERS COULD BE USED SAFELY. (SEE A, 1, ABOVE).

C. POWER AND TELEPHONE LINES OVER 25 FEET ABOVE THE GROUND.

D. BROAD VEGETATIVE TYPES. THESE SHOULD BE NOTED EITHER ON THE AIR OPERATIONS MAP OR ON A SEPARATE MAP. AIR TANKERS IN 1959 WERE ALMOST ALWAYS EFFECTIVE ON FIRES OCCURRING IN GRASS, WOODLAND, OR SCATTERED BRUSH TYPES. ON THE OTHER HAND THEY WERE INEFFECTIVE ABOUT AS MANY TIMES AS THEY WERE EFFECTIVE ON FIRES IN DENSE BRUSH; IN SUCH TYPES THEY SHOULD THEREFORE NOT ALWAYS BE RELIED UPON TO PERFORM AN EFFECTIVE CONTROL JOB.

THEIR EFFECTIVENESS ON TIMBER FIRES VARIED CONSIDERABLY. IN 1959 THEIR ACTION WAS USUALLY INEFFECTIVE ON THE PERIMETERS OF HOT, CROWNING TIMBER FIRES ALTHOUGH THEY PERFORMED SEVERAL GOOD JOBS OF HITTING SPOT FIRES IN THE ADVANCE OF THE MAIN FIRE. LARGER TYPES OF AIR TANKERS ARE MORE LIKELY TO BE SUCCESSFUL IN THESE SITUATIONS, BUT EVEN THEY CANNOT BE RELIED UPON IN EVERY CASE. IF FIRE WAS CONFINED TO GROUND COVER BENEATH THE TIMBER CANOPY, AIR TANKERS WERE USUALLY NOT NEEDED BECAUSE OF EASE OF CONTROL BY GROUND FORCES OR BECAUSE THE RETARDANT COULD NOT PENETRATE THE TIMBER CANOPY AND REACH THE GROUND FUEL.

3. COMMUNICATIONS:

GOOD COMMUNICATIONS FROM GROUND TO AIR, AIR TO AIR, AND ONE AGENCY TO ANOTHER IS AN ABSOLUTE NECESSITY FOR SUCCESSFUL USE OF AIR TANKERS. NO AIR TANKER PROGRAM SHOULD BE ATTEMPTED WITHOUT PLANNING AND PROVIDING AN ADEQUATE COMMUNICATIONS SYSTEM, INCLUDING A SEPARATE AIR NET. THIS FACT WAS AGAIN EVIDENCED TIME AFTER TIME IN 1959.

4. EVALUATION OF AIR TANKERS AND PILOTS:

AN EVALUATION OF AIR TANKERS AND PILOTS SHOULD BE PLANNED. IF AFTER A REASONABLE TRAINING PERIOD (E.G., 50 DROPS) A TANKER AND/OR PILOT DO NOT APPEAR TO BE PERFORMING A SATISFACTORY JOB, THEIR DISMISSAL SHOULD BE SERIOUSLY CONSIDERED.

5. ADEQUATE FACILITIES:

DOWN-TIME OF AIR TANKERS BETWEEN TRIPS TO A FIRE ON A SUSTAINED OPERATION SHOULD BE REDUCED TO A REASONABLE MINIMUM. A SUGGESTED GOAL IS A MAXIMUM AVERAGE DOWN-TIME OF FIVE MINUTES FOR REFILLING WITH RETARDANT AND SERVICING OF THE AIRCRAFT. FACILITIES AND PERSONNEL SHOULD BE PLANNED AND BUDGETED TO MEET THIS GOAL FOR THE LARGEST AIR TANKER TYPE CONTEMPLATED FOR USE AT ANY GIVEN AIRPORT. THIS PLANNING MAY INCLUDE THE NEED FOR LARGER TRANSFER PUMPS, MORE THAN ONE TRANSFER PUMP, LARGER LOADING HOSES, ADDITIONAL LOADING hoses making it possible to use two or more hoses to load the larger planes, more adequate mixing and storing facilities, better servicing facilities, etc.

1959 data on down-time for various air tanker types is included in Table 3 and show that the times varied from an average of six minutes for N3N's to an average of 15 minutes for F7F's. This down-time is wasted time insofar as effective action on the fire is concerned and must therefore be minimized. One reason often given by fire managers for the ineffectiveness of air tankers on fires in 1959 was, "Round-trip time was too long. The fire flanked the drops while the air tankers were gone. Just a few minutes less for round-trips could have resulted in successful action by the air tankers."

- Initial attack dispatching -

1. Quick dispatching:

Air tankers should be dispatched on initial attack in much the same manner as any other tool, i.e., the dispatcher must ask himself for each fire reported, "What is the probable situation? What fire tool (crew, bulldozer, air tanker, helicopter, patrolman, etc.) is most likely to be an economic success in this situation? Which tool can be expected to reach the fire first?" If the answers to these questions indicate the air tankers should be dispatched at once, then they should be sent. If there is a high degree of uncertainty, then they should not be dispatched unless subsequently requested by the fire manager.

The 1959 data showed in several ways that air tankers when needed, were most effective when they were dispatched quickly and arrived at the fires while they were still small (fig. 8). Many times

Fig. 8. Air tankers are most effective when they arrive at a fire while it is still small.

GROUND CREW LEADERS AND FIRE MANAGERS REPORTED "ANOTHER MINUTE OR TWO WOULD HAVE MEANT THE DIFFERENCE BETWEEN SUCCESS OR FAILURE" OF AIR TANKERS IN HELPING TO KEEP FIRE SIZE SMALL IN THE INITIAL ATTACK STAGES.

2. WIND:

WINDS OVER 20 MILES PER HOUR SHARPLY REDUCED AIR TANKER EFFECTIVENESS. ON AT LEAST TWO OR THREE FIRES IN 1959, HOWEVER, THEY WERE JUDGED TO BE THE MOST IMPORTANT TOOL IN HOLDING FIRES TO MUCH SMALLER ACREAGES THAN WAS EXPECTED UNDER WIND CONDITIONS OF 30-40 MILES PER HOUR. WHEN WINDS WERE LESS THAN 10 MILES PER HOUR, AIR TANKERS WERE NOT NEEDED A THIRD OF THE TIME.

3. TOPOGRAPHY:

IN 1959 THE AIR TANKERS WERE ALMOST ALWAYS JUDGED EITHER "EFFECTIVE" OR "NOT NEEDED" ON FIRES OCCURRING IN TOPOGRAPHY JUDGED TO BE FLAT, GENTLY SLOPING, OR ROLLING. INEFFECTIVENESS INCREASED SHARPLY WHEN TERRAIN WAS JUDGED AS STEEP OR VERY STEEP. AT LEAST SOME OF THIS INEFFECTIVENESS WAS DUE TO IMPROPER TACTICAL USE OF AIR TANKERS IN SUCH TERRAIN. SOME OF THE INEFFECTIVENESS WAS ALSO DUE TO THE INABILITY OF THE TANKERS TO MANEUVER AND PERFORM WELL IN STEEP TERRAIN.

4. TEMPERATURE:

INITIAL ATTACK AIR TANKER ACTION IN 1959 WAS JUDGED "NOT NEEDED" IN FOUR OUT OF TEN CASES WHEN THE AIR TEMPERATURE WAS LESS THAN 80°F. THIS RATIO WAS DECREASED SHARPLY TO THE OVERALL RATIO OF LESS THAN THREE OUT OF TEN CASES WHEN THE AIR TEMPERATURE WAS 80°F OR GREATER.

5. BURNING INDEX:

THE CALIFORNIA BURNING INDEX WAS NOT TOO WELL CORRELATED WITH AIR TANKER EFFECTIVENESS. THE TANKERS GENERALLY WERE NOT USED WHEN THE INDEX WAS BELOW 9 (I.E., "LOW"), BUT THE FEW TIMES THEY WERE USED IN THIS CATEGORY FOUND THEM JUDGED ABOUT EQUALLY "EFFECTIVE" OR "NOT NEEDED", BUT NEVER "INEFFECTIVE." THE DATA SHOWED THAT THEY WERE VIRTUALLY ALWAYS NEEDED WHEN THE INDEX WAS ABOVE 26 (I.E., "EXTREME"), ALTHOUGH THEY WERE EFFECTIVE ON ONLY ABOUT HALF THE FIRES BURNING IN THIS CATEGORY. NO COMPARISON OF EFFECTIVENESS TO INTENSITY INDEX WAS MADE, AND IT IS POSSIBLE THAT BETTER CORRELATION MAY BE FOUND WITH THIS INDEX THAN WITH THE TOTAL BURNING INDEX FOR BRUSH AND TIMBER FIRES. REFINEMENT OF THE RELATIVELY NEW BURNING INDEX MAY ALSO BRING ABOUT BETTER CORRELATION IN THE FUTURE.

6. TIME OF DAY:

THE 1959 DATA SHOWED FAIR CORRELATION BETWEEN AIR TANKER EFFECTIVENESS AND TIME OF DAY THAT FIRES WERE REPORTED. THE GREATEST DEGREE OF INEFFECTIVENESS OCCURRED ON FIRES REPORTED BETWEEN 1000 AND 1400 P.D.T. (AIR TANKERS WERE RARELY PLACED ON STANDBY READY

FOR USE PRIOR TO 1000 P.D.T. AND OCCASIONALLY NOT UNTIL 1200 P.D.T., DEPENDING ON THE BURNING INDEX). EFFECTIVENESS INCREASED SHARPLY ON FIRES REPORTED AFTER 1400 P.D.T. THE SUN CASTS LONG, DARK SHADOWS IN BOTH EARLY MORNING AND LATE AFTERNOON HOURS WHICH MAKE IT DIFFICULT FOR THE PILOT TO SEE THE TARGET AND ALSO GROUND OBSTRUCTIONS, THUS DECREASING THE PILOT'S ACCURACY IN DROPPING THE RETARDANT. THIS FACT SHOULD BE KEPT IN MIND IN DISPATCHING.

7. CREW GETAWAY AND TRAVEL TIME:

AIR TANKERS WERE OFTEN NOT NEEDED WHEN CREW GETAWAY AND TRAVEL TIME WERE LESS THAN 10 MINUTES, ALTHOUGH THIS WAS TRUE IN ONLY A THIRD OF THE CASES IN 1959.

8. DISTANCE TO FIRE:

AIR TANKERS WERE ALMOST NEVER JUDGED "INEFFECTIVE" WHEN THE DISTANCE TO THE FIRE FROM THE AIRPORT WAS 20 MILES OR LESS. INEFFECTIVENESS, ESPECIALLY FOR THE SMALLER PLANES, INCREASED SHARPLY ABOVE THAT DISTANCE, ALMOST EQUALING THE NUMBER OF CASES IN WHICH AIR TANKERS WERE EFFECTIVE. THIS POINT SUPPORTS THE GENERAL PRINCIPLE THAT AIR TANKERS ARE MOST EFFECTIVE WHEN THEY REACH FIRES QUICKLY.

9. RATE OF SPREAD:

AIR TANKERS WERE VIRTUALLY ALWAYS NEEDED WHEN A FIRE'S RATE OF SPREAD WAS JUDGED AS FAST OR EXTREME, ALTHOUGH THERE WAS ALMOST AN EVEN CHANCE OF THEIR BEING JUDGED "EFFECTIVE" OR "INEFFECTIVE" IN THEIR CONTROL CONTRIBUTION. RARELY WERE THE AIR TANKERS INEFFECTIVE ON FIRES JUDGED TO BE BURNING SLOW OR MODERATELY FAST.

10. SPECIAL CASE:

AIR TANKERS USUALLY WERE NOT NEEDED ON FIRES WHICH STARTED UNDER THE COMBINED CONDITIONS OF BEING LATE IN THE DAY, ON THE SHADED SIDES OF RIDGES, AND IN DENSE WOODLAND OR TIMBER. THESE COMBINED CONDITIONS TENDED TO CONTRIBUTE TO RISING RELATIVE HUMIDITY AND FINE FUEL MOISTURE CONTENT AND TO LOWERING TEMPERATURE AND BURNING INDEX, RESULTING IN A LOW RATE OF FIRE PERIMETER SPREAD WHICH COULD BE HANDLED READILY BY GROUND FORCES.

11. WET LIGHTNING FIRES:

AIR TANKERS WERE OFTEN NOT NEEDED IN 1959 ON LIGHTNING FIRES STARTED BY THUNDERSTORMS FROM WHICH CONSIDERABLE MOISTURE REACHED THE GROUND. NORMALLY EVEN A LARGE NUMBER OF SUCH FIRES CAN BE PICKED UP BY GROUND FORCES. IF ALL LIGHTNING FIRES ARE NOT PICKED UP WITHIN 24 HOURS, OR IF THE BRUSH OR TIMBER INTENSITY INDEX IS HIGH PREVIOUS TO THE STORM, AIR TANKERS WILL LIKELY BE NEEDED. THE AMOUNT AND DISTRIBUTION OF PRECIPITATION ARE THE KEYS TO MAKING A DECISION IN THIS SITUATION.

1. Communications:

Until the communications problem was solved in 1959, ground crew leaders gave this reason most often (and in the strongest language!) as the principal factor contributing to ineffective use of air tankers. Coordination between ground and air forces is almost impossible without adequate communications.

2. Drop coordinator:

The activity and safety of air tankers on a forest fire must be controlled at all times by the drop coordinator. The dropco must determine the presence of all aircraft on a fire, maintain knowledge of their location at all times, direct their orbiting and flight patterns and direct the retardant drops of the air tankers. To perform this highly important job and to obtain maximum efficiency of a very costly tool requires the efforts of a person who is both a strong supervisor and an experienced fire control technician, and who possesses sufficient administrative rank to command respect of decision from both ground and air personnel.

3. Fire boss-drop coordinator relationship:

The fire boss and the drop coordinator, or the air tanker pilots in the absence of a drop coordinator, must at all times coordinate closely the ground and air suppression efforts (fig. 9). Many times in 1959 either the ground or the air forces cancelled the good efforts of the other through the lack of coordination of activity between the two.

Fig. 9. The fire control efforts of air and ground forces must be closely coordinated for maximum effectiveness. Photo by Los Angeles County Fire Department.

4. Coordination among pilots:

Air tanker pilots should closely coordinate their activities not only with ground units but also among themselves. They should not drop indiscriminately but should attempt to build continuous retardant lines unless they have been given specific instructions to the contrary.

5. Series of sets:

If there is a series of fire sets, air tankers may best be used on the smallest and/or the most isolated fire while the bulk of the ground units attack the larger and more accessible fire or fires. The air tankers should attack the isolated fire, however, only if they can be reasonably expected to contain it entirely or can rely upon early ground support.

6. Critiques:

It is important that ground and air personnel have critiques as often as possible following fires on which air tankers are used. Too often in the past, problems between ground and air forces have been repeated and compounded needlessly. Frequent, short meetings can be the best means of obtaining maximum coordination between ground and air forces. All agencies taking part in the fire action should be represented at these critiques.

- Tactical use of air tankers on fires -

1. Primary criterion of use:

The primary criterion in the use of air tankers on forest fires is to use them in the same manner as any other fire tool, with essentially the same strategy and tactics. Common sense and fire sense will always be the best guides and are intended to be implied in the following criteria of air tanker use.

2. Line location:

As with any other tool, air tankers should be directed to attack that portion of the fire line where their chance of success in halting or slowing the fire's spread is maximum. First choice of attack should always be the head of a fire but only if such an attack can reasonably be expected to hold the fire without the danger of being outflanked and of compounding the fire control problem.

If there is a choice, air tankers should be directed to construct their retardant line in the lighter fuels where the 1959 data showed they were most effective. Often this will mean making a continuous, indirect line at some distance from the fire. Many times in the past, retardant lines which were built too close to the fire line were outflanked by the fire before they were completed. The actual distance of the drops from the fire depends

LARGELY UPON THE FUEL TYPES IN THE AREA, INTENSITY AND RATE OF SPREAD OF THE FIRE, POSSIBLE FOLLOW-UP BY GROUND FORCES, NUMBER AND SIZE OF AIR TANKERS INVOLVED IN THE ACTION, AND ROUND-TRIP TIME TO THE REFILL AIRPORT.

3. SMALL FIRES:

AIR TANKERS ARE MOST SUCCESSFUL ON SMALL FIRES WHICH OFTEN CAN BE ENTIRELY SURROUNDED AND HELD BY RETARDANT DROPS. IF, HOWEVER, NO GROUND UNITS ARE IMMEDIATELY AVAILABLE FOR FOLLOW-UP ACTION AND THE AIR PERSONNEL FEEL THEY CANNOT ENTIRELY CONTAIN A FIRE PERIMETER WITH THEIR FIRST SERIES OF DROPS, THEY SHOULD USUALLY ATTACK THE FLANKS OF A FIRE RATHER THAN ATTEMPT TO STOP THE HEAD. IF THERE CAN BE NO EARLY FOLLOW-UP ACTION, EVEN A SLOW-MOVING FIRE WILL OFTEN OUTFLANK A DISCONTINUOUS RETARDANT LINE LAID ACROSS ITS HEAD AND POSSIBLY RESULT IN TWO HEADS SPREADING IN DIFFERENT DIRECTIONS. THE USE OF GOOD FIRE SENSE IN SIZING UP THE FIRE SHOULD PROVIDE THE CORRECT ANSWER MORE TIMES THAN NOT.

4. LARGE FIRES:

SELDOM ARE DROPS SUCCESSFUL ACROSS THE HEADS OF LARGE FIRES. AIR TANKERS CAN BE DIRECTED TO PERFORM THEIR MOST EFFECTIVE ACTION ON FLANKS, HOT SPOTS, AND SPOT FIRES. THEY CAN ALSO BE USED EFFECTIVELY IN PRETREATING RIDGES WELL IN ADVANCE OF THE MAIN FIRE OR IN WIDENING ESTABLISHED CONTROL LINES.

5. FAST MOVING FIRES:

ON FAST MOVING FIRES AIR TANKERS CAN BE USED MOST EFFECTIVELY ON THE FLANKS, UNLESS THE HEAD IS NARROW ENOUGH TO BE STOPPED BY ONE OR TWO DROPS. EVEN FLANKING DROPS SHOULD NOT BE MADE INDISCRIMINATELY BUT SHOULD BE TIED TO AN ESTABLISHED FIRE-BREAK AND BE LAID CONTINUOUSLY UNLESS THERE IS GOOD REASON FOR HOT-SPOTTING SPECIFIC TARGETS.

6. FIRES ON STEEP SLOPES:

HITTING THE HEAD OF ANY HOT FIRE BURNING SWIFTLY UP A STEEP SLOPE IN HEAVY FUELS IS RARELY EFFECTIVE SINCE THE FIRE WILL MOST OFTEN SPOT ACROSS THE DROP ALMOST AT ONCE, ESPECIALLY IN HEAVIER FUEL TYPES. IN THESE CASES MORE EFFECTIVE ACTION CAN USUALLY BE TAKEN BY PRETREATING THE RIDGE OR A BROAD BENCH WHERE THE FIRE SPREAD WILL SLOW DOWN. A CHANGE TO A LIGHTER FUEL TYPE MAY ALSO PRESENT POSSIBILITIES FOR PRETREATMENT AND MORE CERTAIN CONTROL.

7. HIGH INTENSITY FIRES:

ON HIGH INTENSITY FIRES OR ON FIRES BURNING IN HEAVY FUELS, VOLUME OF RETARDANT MAY BE DESIRABLE, REQUIRING EITHER LARGER AIR TANKERS OR AN OVERLAPPING OF DROPS OF SMALLER AIR TANKERS.

8. Sustained action:

Sustained use of air tankers on large fires over a period of two or more days requires careful planning by the fire boss. If air tanker use is probable for all daylight hours (12-14 hours), plans must be made for pilot relief, adequate aircraft servicing and maintenance, adequate supplies of retardants and possible relief of airport facility personnel, depending on the size of the proposed operation. If air tankers are to be needed for dropping as soon as the first light of day permits low flying in safety, then plans must be made to service and maintain aircraft during the previous night and to arrange for take-off from the airport so that the air tankers are orbiting over the fire at dawn, prepared for dropping retardant as soon as it can be safely applied and air action can be coordinated with ground forces.

9. Mop-up action:

Rarely should air tankers be used on mop-up action which usually can be done much better by ground forces. They are too expensive a tool to use in such action unless there is an important need to cool a particularly threatening piece of line.

- Drop techniques -

1. Optimum ground pattern:

Each pilot should be well acquainted with the altitudes (above the top of the vegetation) and air speeds and gate openings for his specific air tanker which produce the optimum ground pattern for various vegetative types and fire situations. These three factors vary for individual air tankers. Normally the same altitude and speed will be desirable for most fire situations. In grass or in other fuel types giving low intensity fires, the concentration of retardant per unit of ground area may be decreased considerably; therefore it is desirable to increase both height and speed and/or decrease gate opening, causing a given volume of retardant to produce a longer pattern with lower concentration of retardant per unit area, thus making more efficient use of the load. It must be remembered that G-loading considerably alters the drop pattern and should be avoided whenever a drop can be made from flight parallel to the ground surface.

2. Low drops:

All drop tests to date show that no air tanker with tank and gate configurations specified by California firefighting agencies (4) should fly lower than 50 feet at any time. Drops made from a lower altitude produce a small ground pattern with a much higher than normally necessary concentration of retardant, thus decreasing efficiency of the load. In 1959 low drops on at least four different Division of Forestry fires were blamed for causing the fire to spread quickly when hit by the prop wash of air tankers. Low drops have also caused fatal and near-fatal accidents to personnel and have damaged equipment (fig. 10). While low drops will produce a higher concentration of retardant per unit area (over a smaller area for a given load), such a concentration, if deemed desirable, should be obtained by using a larger capacity air tanker or by overlapping drops of smaller tankers; it should never be obtained by dropping from a lower altitude.

Fig. 10. Retardants dropped at too low an altitude can damage equipment.

3. Judging altitude:

Tests have shown that rarely can pilots accurately judge low altitudes (8). A continuous effort must be made, therefore, to train pilots in their ability to judge such key heights as 50, 75, and 100 feet. One way of learning is to fly adjacent to objects whose heights are known, such as high power lines, trees, or towers.

4. Drops at right angles to fire line:

Drops should not be made at right angles to a fire line unless the air tanker is hot-spotting a small area and there is no other good approach. Such drops make use of only the width of the drop pattern rather than the length, wasting retardant. Also such drops often enter into the convection column of the fire and are carried upward, doing no good toward helping to suppress the fire.

5. HIGH WINDS:

WHEN OPERATING IN WINDS ABOVE 20 MILES PER HOUR, AIR TANKERS SHOULD FLY INTO THE WIND FOR SAFETY OF OPERATION, ALLOWING FOR DRIFT OF THE RETARDANT WHEN DROPPING.

- SAFETY -

1. FLYING HAZARDS:

STEEP TOPOGRAPHY AND DEEP CANYONS, DENSE SMOKE, HIGH TIMBER AND SNAGS, SHIFTING AND HIGH VELOCITY WINDS, AND TURBULENT AIR ARE ALL DEFINITE FLYING HAZARDS AND WERE REPORTED OFTEN IN 1959 AS CAUSING HIGH DROPS AND CONSEQUENT DRIFTING OF THE RETARDANT INTO INEFFECTIVE GROUND PATTERNS. OCCASIONALLY ANY ONE OF THESE FACTORS MAY RESTRICT OR EXCLUDE THE USE OF AIR TANKERS.

2. THUNDERCLOUDS:

THUNDERCLOUDS IN THE VICINITY OF A FIRE WILL CREATE DANGEROUS DOWNDRAFTS WHICH NOT ONLY ARE A HAZARD TO AIRCRAFT BUT ALSO MAY CAUSE SUDDEN SHIFTS IN FIRE SPREAD. SUCH SITUATIONS WERE REPORTED SEVERAL TIMES IN 1959.

3. TELEPHONE AND POWER LINES:

THE LOCATION OF HIGH TELEPHONE AND POWER LINES IN OR ADJACENT TO A FIRE AREA SHOULD BE COMMUNICATED TO AIR TANKERS BY EITHER THE DISPATCHER, WHO SHOULD HAVE THIS INFORMATION ON HIS AIR OPERATIONS MAP, OR PERSONNEL ALREADY ON THE FIRE.

4. NEARBY AIRPORTS:

THE PROXIMITY OF AIRPORTS WITH HEAVY TRAFFIC CAN BE A DEFINITE HAZARD TO AIR OPERATIONS ON A FOREST FIRE. THIS IS PARTICULARLY TRUE WHEN FIRES OCCUR NEAR MILITARY AIR BASES WHERE MANY JET AIRCRAFT REQUIRE A LARGE RADIUS FOR ORBITING AND APPROACHING THEIR BASE OF OPERATIONS. DISPATCHERS SHOULD RECOGNIZE THESE SITUATIONS (BY PREVIOUSLY NOTING SUCH MILITARY BASES ON THE AIR OPERATIONS MAP) AND COMMUNICATE THE POTENTIAL DANGER BOTH TO AIRCRAFT OPERATING ON THE FIRE AND TO THE AIR CONTROL PERSONNEL AT THE MILITARY BASE.

5. LOW FLYING:

THE DANGERS OF AIR TANKERS FLYING BELOW 50 FEET IN ALTITUDE HAS ALREADY BEEN NOTED IN THE SECTION ON DROP TECHNIQUES.

6. CONTROL OF AIRCRAFT ACTION:

THE NEED FOR ADEQUATE COMMUNICATIONS TO PROVIDE COORDINATION OF EFFORT, GROUND-TO-AIR, AIR-TO-AIR, AND AGENCY-TO-AGENCY, HAS ALREADY BEEN STRESSED. ADEQUATE COMMUNICATIONS ARE ALSO NECESSARY FOR SAFETY OF OPERATION. AIRCRAFT OF ALL TYPES OPERATING ON A FOREST FIRE MUST BE CONTROLLED AT ALL TIMES BY ONE PERSON IN COMMAND (USUALLY THE drop coordinator on Division of Forestry fires) if mid-air collisions are to be avoided and if safe, coordinated fire control effort is to be maintained. Instructions from the control officer for orbiting and dropping must be followed implicitly by the air tanker pilot unless he feels the instructions are beyond the capabilities of his tanker, in which case he should simply inform the control officer of this fact and await further instructions. Air tanker pilots should keep the drop coordinator informed of any potential dangers they may note.

7. Disagreements:

Arguments as to tactics during the time of the air operation can only cause confusion and endanger the entire fire control job of the air tankers. The drop coordinator will control air activities. Any disagreements should be discussed at a critique following the end of operations.

8. Time of day:

The hazards to safe flying created by long shadows both early in the day and late in the afternoon have already been mentioned and must be considered not only by pilots but by fire control personnel using the air tankers on fires.

USE OF FIRE RETARDANTS

Table 4 shows the use of retardants by the Division of Forestry in 1959.

Table 4. Retardant use by Division of Forestry, 1959, (Gallons).

District	No. drops	Borate	Bentonite	Total
I	264	14,485	50,055	64,540
II	921	152,610	2,360	154,970
III	385	128,985	4,750	133,735
IV	100	22,620	-0-	22,620
V	3	1,600	-0-	1,600
VI	372	117,160	70,110	187,270
Totals	2,045	437,460	127,275	564,735

The average cost per gallon of retardant delivered to Division fires in 1959 by various air tanker types was as follows:

	Bentonite	Borate
Average cost of delivery.	$.255	$.255
Cost of material.	.015	.166
Total	$.270	$.421

Note that the figures reflect only the cost of flight time and the cost of the dry materials used to mix the retardant slurry; they do not include the cost of standby time for air tankers nor the cost of mixing, storing, and loading the retardant.

Although the Division used air tankers on about 80 fewer fires in 1959 than in 1958, the total use of retardant was about the same for the two years. The principal change was the use of bentonite in 1959, particularly in Districts I and VI.

Problems with bentonite

1959 was the first year in which swelling bentonite clay slurry was used operationally in large quantities on forest fires (9). As has been the experience of firefighting agencies with other retardants in the past, difficulties were encountered in the early mixing and use of bentonite slurry (10). The tendency by all using agencies was to mix bentonite too thinly, causing it to drift when dropped from air tankers and considerably decreasing the length of time it would retain an effective quantity of water for fire retarding purposes. These early failures and misunderstandings of what constituted a "proper mix" discouraged some users of bentonite and gave rise to many conflicting stories of its effectiveness as compared to borate.

These conflicting stories resulted in cooperative drop tests being conducted at Ramona Airport in San Diego by the California Air Attack Coordinating Committee[4/] (4). Briefly, the results indicated that there was no significant difference in the drop characteristics between borate and bentonite when dropped from air tankers flying at various heights and speeds; viscosity ("thickness" of slurry) was more important than weight per gallon in producing good drop patterns of any retardant slurry; and increasing the height and speed of air tankers increased the drift of any retardant slurry dropped.

4/ The California Air Attack Coordinating Committee includes representatives from the U. S. Forest Service Regional Office, Arcadia Equipment Development Center, Pacific Southwest Forest and Range Experiment Station, Los Angeles County Fire Department, and the Division of Forestry. The Committee's function is to coordinate in California research and equipment development in air attack on forest fires.

Improvement of bentonite slurry

The early use of too thin a bentonite slurry resulted in several failures, as previously noted:

Mendocino #228 5/: "Bentonite was too dispersed when hitting the ground although it did slow the fire considerably and stopped some spots completely."

Lake #62: "Bentonite breaking into fine mist before hitting ground."

The same problems, however, can be encountered with borate slurry or any retardant that is mixed improperly:

Lake #60: "Borate was too thin, drifting in many cases."

Several weeks were needed before the fire agencies learned the proper proportions of bentonite and local water needed to produce as thick a slurry as possible that could still be moved by the available transfer pump. Water was found to be the most critical factor; hard water and alkaline water both required larger proportions of bentonite than normal. Division of Forestry personnel found .85 pounds of bentonite per gallon of water were needed at Ukiah in District I, whereas .9 pounds were needed with harder water at Ramona, and nearly 1.5 pounds with alkaline water at Hemet in District VI.

After the bentonite slurry was thickened to the proper viscosity, comments from the field were quite favorable:

Sonoma #269: "Bentonite drops held fire for 90 minutes until crews arrived."

Mendocino #220: "No areas observed where fire burned through bentonite or spotted over."

San Diego #267: "Bentonite really doing a good job."

Summary Report, 1959, Ramona Airport: "As a retardant bentonite was considered not to be able to hold like borate. However, I saw many times where bentonite held just as long as borate, and in some cases it held where fire had burned through borate drops."

Tactical use of fire retardants

It is probable that both borate and bentonite will continue to be used as fire retardants by the California Division of Forestry in 1960, based upon experience in 1959.

5/ Fires are identified by Ranger Unit and fire number within the Unit. Quotations are those of personnel who took part in fire control action on the fires.

1) Line-holding ability

Bentonite should be used either in direct attack or in indirect attack when the constructed line is likely to be reached by the fire within at least one or two hours at the most. Beyond that time bentonite no longer will hold sufficient water to retard fire spread:

San Diego #224: "Pre-treated area with bentonite. Held for one hour and then fire burned through."

The actual lapsed time will vary up to a two hour period depending on the drying conditions, the amount of fuel and the fire's heat intensity. Bentonite should hold for the maximum period in light grass or for slower burning fires with low heat intensity. At the other extreme bentonite, or any retardant, will not hold against the head of a fast moving, high heat intensity fire burning in heavy brush or crowning in timber. On such fires retardants will more often be successful if dropped on the slower moving flanks.

In general, then, it can be said that either borate or bentonite can be used in most initial attack situations while only borate should be used when pre-treatment for periods of more than one and a half or two hours is desirable. The fact that bentonite slurry is 15 cents cheaper per gallon than borate slurry should be kept in mind.

2) Penetration

More complete tests have yet to be conducted to determine the penetrability of borate and bentonite. The Ramona tests indicated that viscosity may be more important than weight in the drop pattern of a retardant, but to date there is inconclusive evidence and conflicting reports from 1959 fires regarding penetration characteristics:

Lake #61: "Retardant not penetrating real heavy brush." This was in early use of bentonite in District I when it was quite a thin slurry.

Lake #73: "Bentonite was thick and giving good penetration."

Mendocino #220: "Bentonite seemed to penetrate well."

Summary Report, Ramona Airport: "Bentonite was used on initial attack but sometimes borate was called for by the fire boss for penetrating work."

Calaveras #110: "Borate could not penetrate tall timber deeply enough to hold the ground fire."

At this stage of development of retardants, then, no specific recommendations can be made as to what characteristics a retardant should have in order to penetrate well a dense timber or brush canopy.

3) Visibility of retardants

Air tanker pilots should be able to detect previous drops so that they can continue an unbroken line of fire retardant. Borate is ideal in this respect in that its particles dry rather quickly and leave a highly visible white coating. Bentonite particles, on the other hand, remain wet for a long time and, unless the slurry is artificially colored, drops cannot be seen. Pink aniline dye (Rhodamine B) is recommended as the best compromise in color for bentonite slurry for all vegetative types, being visible in grass, brush, and timber. If the majority of fires are in grass, a brighter red aniline dye would be preferable, although it does not show up well in brush or timber. If the majority of fires are in brush or timber, yellow aniline dye (Auromine O) would be preferable, although it shows up poorly in dry grass (10). It is probable that these same colors should apply with other retardants that may be developed in the future.

Future studies

Tests to date by the Pacific Southwest Forest and Range Experiment Station, with whom the Division of Forestry is engaged in a cooperative fire retardant research program, show that borate and bentonite are the best retardants presently available. Tests will be continued during 1960, however, with a vermiculite-bentonite mixture, "viscous water" (water plus viscosity agents for thickening), a bentonite-foamite mixture, and ammonium phosphate. The latter material has shown considerable promise in tests in the Southeastern United States and in California (1, 6).

The Division will also take part in a cooperative study of retardant drop impact with the other members of the California Air Attack Coordinating Committee. It is hoped that these tests will point out safety measures that should be taken by ground personnel located in the vicinity of air tanker operations and also point out drop techniques that should, or should not, be practiced by air tankers in order to provide a necessary degree of safety to ground personnel.

Current studies of retardant mixers by the Arcadia Equipment Development Center, U. S. Forest Service, may give further clues for improving the water-holding ability of bentonite. Indications to date are that completeness of hydration of the dry bentonite particles may be directly proportional to the energy used in combining the bentonite and water into a slurry. The studies should give leads as to the best methods of mixing slurries.

Other questions remain concerning fire retardants. While the Ramona tests in 1959 showed that viscosity was more important than weight in producing a good drop pattern, the effect of a large range of viscosities has not yet been determined. We need to know what retardant characteristics are desirable to give maximum penetration of dense timber and brush canopies: viscosity? weight per gallon? some other factor? Perhaps cohesion, independent of weight and viscosity, is important in penetration and in free-fall drop patterns. Also, exactly what concentration of different retardants are required for fires burning with different intensities and in different fuel types? At present we know less dense concen-

TRATIONS ARE NEEDED IN THE LIGHTER FUELS AND ON FIRES OF LOW HEAT INTENSITY. BUT WHAT ARE THE AMOUNTS OF RETARDANT NEEDED PER UNIT GROUND AREA UNDER DIFFERENT CONDITIONS? HOW CAN WE DIRECT AIR TANKER PILOTS SO THEY CAN PRODUCE MAXIMUM EFFICIENCY OF THEIR TOTAL RETARDANT LOAD UNDER VARYING FIRE CONDITIONS? OF WHAT IMPORTANCE IS THE CHARACTERISTIC OF ADHESION IN A RETARDANT'S ABILITY TO COAT FOREST FUELS AND SLOW A FIRE'S SPREAD? CAN LIQUID NITROGEN AND/OR LIQUID CARBON DIOXIDE BE APPLIED SAFELY AS FIRE SUPPRESSANTS OR RETARDANTS? THESE AND OTHER QUESTIONS MUST YET BE ANSWERED BEFORE IT CAN BE SAID WE ARE DOING THE BEST JOB POSSIBLE WITH FIRE RETARDANTS AND AIR TANKERS.

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APPENDIX

Formula for Measuring Theoretical Capability of Air Tankers to Deliver Retardant to a Forest Fire

As noted in the section, "Use of Air Tankers on Forest Fires," the capability of different air tankers to deliver retardant to a fire varies with volume of load, rate of speed, number of trips to the fire on a sustained operation, distance to the fire from the airport, and average down-time needed for refilling, servicing, maintenance, etc., between trips. These factors can be combined into a formula which can be used by an air program administrator as one basis for planning his air tanker operation:

$$C.I. = \frac{VN}{\left[\frac{120\,ND}{R}\right] + \left[T\,(N-1)\right]} = \frac{\text{Gallons retardant delivered}}{\text{Minute}}$$

C.I. = Capability index, in gallons per minute
V = Capacity of air tanker, in gallons
N = number of trips made to fire on a sustained operation
D = distance to fire from airport, one-way, in miles
R = rate of speed of air tanker, in miles per hour (round-trip average)
120 = conversion factor
T = average down-time at airport between trips of a sustained operation, in minutes

Explanation of Capability Index and Factors

1. C.I. = Capability Index. This index measures the theoretical or actual number of gallons of retardant capable of being delivered per minute by an air tanker. It permits comparing one phase of the performance of one air tanker with any other and can also be used to calculate the cost per hour ratio of one air tanker to any other for contracting purposes.

   According to the formula, C.I. varies with various distances to the fire and the number of trips made to any one fire. The factors R (rate of speed) and T (down-time between trips) are average figures and remain constant once they have been calculated for a given air tanker.

   The index assumes that all gallons of retardant delivered to a fire are dropped with equal accuracy and are equally effective. With present variations in pilot ability, condition of aircraft, maneuverability characteristics, and in tank and gate configurations, this assumption is not entirely correct. It will tend to become increasingly correct, however, as 1) pilots become equally experienced

AND ABLE IN THEIR PERFORMANCE AND 2) AS AIRCRAFT OWNERS CONTINUE TO BUILD NEW TANKS AND GATES WHICH WILL PRODUCE AN OPTIMUM RETARDANT PATTERN ON THE GROUND FOR THEIR INDIVIDUAL AIRCRAFT. UNDER THE LATTER ASSUMPTION A 400 GALLON RETARDANT DROP WILL COVER TWICE THE GROUND AREA AS A 200 GALLON DROP WITH EQUAL EFFECTIVENESS IN ALL PARTS OF THE DROP PATTERN. THIS GOAL IS THEORETICALLY POSSIBLE WITH THE PROPER TANK AND GATE DESIGN AND WITH AN AIR TANKER FLYING AT ITS OPTIMUM HEIGHT AND SPEED.

ALSO ASSUMED IS THAT THE AVERAGE TIME SPENT IN ORBITING AT A FIRE IS EQUAL OVER ALL FIRES FOR ALL AIR TANKERS, CONSIDERING THE HIGH VARIATION OF THIS FACTOR. IF ORBITING TIME CAN ACTUALLY BE MEASURED FOR A SERIES OF FIRES FOR INDIVIDUAL AIR TANKER TYPES, IT COULD EASILY BE INSERTED INTO THE FORMULA.

IGNORED IS THE MANEUVERABILITY OF DIFFERENT AIR TANKER TYPES UNDER DIFFERENT TERRAIN AND WIND CONDITIONS. THIS FACTOR IS IMPORTANT, HOWEVER, ONLY ON A RELATIVELY SMALL BUT CRITICAL PERCENT OF THE TOTAL NUMBER OF DROPS MADE BY AIR TANKERS ON FIRES, AS NOTED IN A STUDY OF SEVERAL THOUSAND FEET OF MOTION PICTURE FILM OF AIR TANKER OPERATIONS.

UNTIL SUCH TIME AS THESE ASSUMPTIONS MAY BECOME FACT, THE USER OF THE FORMULA MAY WISH TO APPLY A CORRECTION FACTOR TO THE INDEX BASED UPON HIS BEST ESTIMATE OF THE COMPARATIVE EFFECTIVENESS OF INDIVIDUAL AIR TANKERS.

2. V = VOLUME OF TANK, IN GALLONS. ASSUME A CONSTANT LOAD EACH TRIP OR USE THE TOTAL OF ACTUAL LOAD VOLUMES.

3. N = NUMBER OF TRIPS MADE TO ONE FIRE OVER A CONSTANT DISTANCE (D) FROM AIRPORT TO FIRE, AND RETURN, ON A SUSTAINED OPERATION.

4. D = DISTANCE TO FIRE FROM AIRPORT, IN MILES. THIS FACTOR IS CONVERTED TO TOTAL ROUND-TRIP DISTANCE BY USING A MULTIPLIER OF "2" (INCLUDED AS PART OF THE CONVERSION FACTOR "120"). THIS PORTION OF THE CONVERSION FACTOR COULD BE ELIMINATED BY MAKING D EQUAL TO ROUND-TRIP DISTANCE. PILOTS AND AIR OPERATIONS PEOPLE ARE FAMILIAR WITH USING THE ONE-WAY DISTANCE TERM, AND IT IS SUGGESTED THAT THE ROUND-TRIP DISTANCE FIGURE COULD OCCASIONALLY CAUSE SOME CONFUSION.

IT IS ASSUMED THAT THE PLANES FLY IN A STRAIGHT LINE DISTANCE FROM THE AIRPORT TO THE FIRE. THIS ASSUMPTION IS NOT ALWAYS CORRECT AND WILL VARY DEPENDING UPON THE TERRAIN (PILOTS MAY TAKE DEVIOUS ROUTES TO AVOID CLIMBING OVER HIGH MOUNTAINS OR FLYING NEAR AREAS OF TURBULENT AIR, ETC.) AND ON THE POWER OF THE AIRCRAFT (SOME AIRCRAFT CAN CLIMB FASTER THAN OTHERS AND THEREBY SELECT A MORE DIRECT ROUTE TO A FIRE WHEN NECESSARY). SINCE THESE FACTORS ARE QUITE VARIABLE AND ONLY OCCASIONALLY CONTRIBUTE TO THE TIME REQUIRED FOR AN INDIVIDUAL AIR TANKER TO REACH A FIRE, THEY ARE IGNORED IN THE FORMULA.

5. R = RATE OF SPEED OF AIR TANKER IN MILES PER HOUR. THE CONVERSION FACTOR OF 120 INCLUDES A FACTOR OF "60" WHICH CONVERTS TIME FROM HOURS TO MINUTES, RESULTING IN A MORE HANDY FIGURE FOR THE CAPABILITY INDEX.

R can be assumed from experience or actually can be calculated over a series of several operations for any given air tanker. It is calculated by measuring the distance (D) to the fire, multiplying by two, and dividing by the time actually required by the air tanker to make the flight to and from the fire. Time required for takeoff, avoiding topographic obstacles en route to and from the fire, orbiting at the fire, and landing would be included in the overall average figure and would tend to decrease the overall average for those aircraft requiring a short takeoff and landing distance and those able to maneuver in tighter places at the scene of a fire.

6. T = Average down-time at the airport between trips on a sustained operation, in minutes. This figure will be relatively small for air tankers with low capacities requiring short refill times and will be relatively large for larger capacity air tankers requiring longer refill times. On a sustained operation it will also reflect the average time required for servicing and maintenance.

Down-time is best estimated by actually measuring the down-times for individual air tankers over a series of sustained operations on forest fires and taking the average. The average down-time (T) is multiplied by (N-1) to give the total down-time between trips on any one fire.

Down-time will tend to become equal for all air tanker types as facilities become adequate at all locations for the handling of the maximum size air tanker and as pilots tend to maintain their aircraft equally well, minimizing emergency failures or shut-downs.

7. The term VN measures the total gallons delivered by an air tanker on a fire.

8. The term $\frac{120\ ND}{R}$ measures the total time in minutes required for flight in the air.

9. The term T (N-1) measures the total time in minutes required for loading, servicing, maintenance, etc., between trips to the fire.

Using this formula and the average figures in Table 3, page 28, the theoretical capabilities of the four air tanker types used in the Division's 1959 experiment were calculated and are shown in Table 5. These figures show that the larger, faster air tanker types had an increasing relative advantage over the smaller, slower tankers as distance to the fire increased, but that the smaller, slower tankers had an increasing relative advantage as the number of trips to the fire increased up to a limit of about six trips.

These results came about largely because of the differences in average down-time. The longer down-times for larger air tanker types were partly due to the admittedly inadequate loading facilities at some of the Division's air bases. Future budgeting should correct these inadequacies.

Table 5. Capability Indexes of air tankers used in 1959.[A/]

C.I.

N= \ D=	N3N	Twin Beech		TBM			F7F			
			Ratio to:		Ratio to			Ratio to		
	C.I.	C.I.	N3N	C.I.	N3N	Tw Bch	C.I.	N3N	Tw Bch	TBM
10 Miles										
2	12.2	23.0	1.89	42.9	3.52	1.87	56.5	4.63	2.46	1.32
6	10.9	18.7	1.72	33.3	3.06	1.78	41.7	3.83	2.23	1.25
10	10.7	18.0	1.68	31.9	2.98	1.77	39.7	3.71	2.21	1.24
14	10.6	17.7	1.67	31.3	2.96	1.76	38.9	3.67	2.18	1.24
20 Miles										
2	6.7	13.9	2.07	27.3	4.07	1.96	38.4	5.73	2.76	1.41
6	6.3	12.2	1.94	23.1	3.67	1.89	31.0	4.92	2.54	1.34
10	6.2	11.9	1.91	22.4	3.60	1.88	29.8	4.80	2.50	1.33
14	6.2	11.8	1.90	22.1	3.56	1.87	29.3	4.72	2.48	1.32
30 Miles										
2	4.7	9.9	2.11	20.0	4.45	2.02	29.1	6.19	2.94	1.46
6	4.4	9.0	2.04	17.6	4.00	1.96	24.6	5.59	2.73	1.40
10	4.4	8.9	2.02	17.2	3.91	1.94	23.9	5.43	2.69	1.39
14	4.4	8.8	2.00	17.1	3.88	1.94	23.6	5.35	2.68	1.38

A/ N = number of round-trips
D = distance to fire
C.I.= Capability Index

Although Table 5 shows only N = 2, 6, 10, and 14, calculations were made also for N = 4, 8, and 12, but the latter figures were deleted from this report for brevity. Figure 11 shows the relationship of the Capability Indexes in graphic form.

Table 6 shows the comparison of contract rates paid for the services of the different air tanker types in 1959 by the Division of Forestry. The ratios can be compared to the Capability Index ratios in Table 5, but again the relationship must be tempered by consideration of the data used and the assumptions made in calculation of the Capability Indexes.

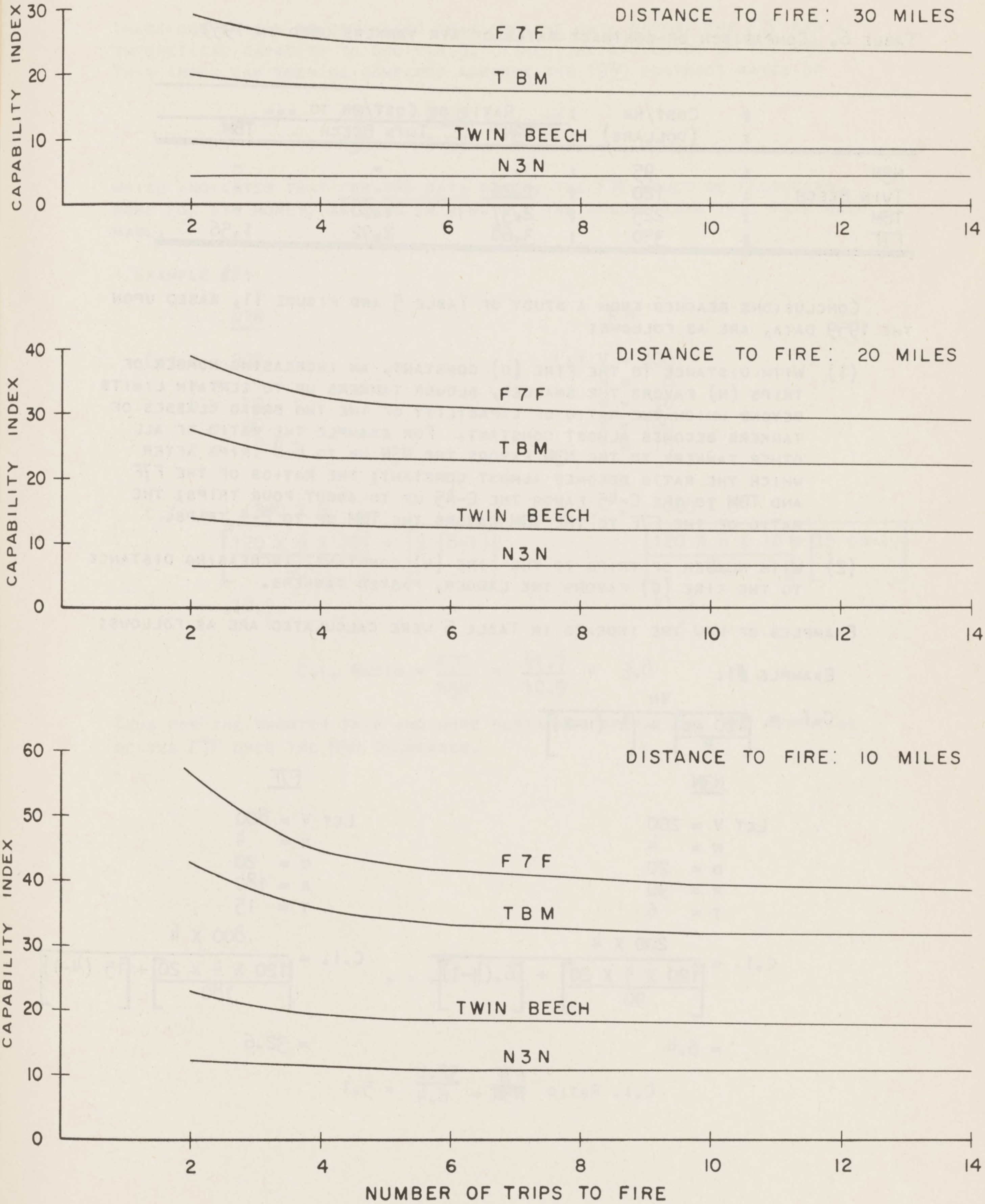

FIG. 11 CAPABILITY INDEXES FOR FOUR AIR TANKERS

TABLE 6. COMPARISON OF CONTRACT RATES OF AIR TANKERS USED IN 1959.

	COST/HR (DOLLARS)	RATIO OF COST/HR TO ...		
		N3N	TWIN BEECH	TBM
N3N	95	-	-	-
TWIN BEECH	120	1.26	-	-
TBM	225	2.37	1.88	-
F7F	350	3.68	2.92	1.56

CONCLUSIONS REACHED FROM A STUDY OF TABLE 5 AND FIGURE 11, BASED UPON THE 1959 DATA, ARE AS FOLLOWS:

(1) WITH DISTANCE TO THE FIRE (D) CONSTANT, AN INCREASING NUMBER OF TRIPS (N) FAVORS THE SMALLER, SLOWER TANKERS UP TO CERTAIN LIMITS BEYOND WHICH THE RATIO OF CAPABILITY OF THE TWO BROAD CLASSES OF TANKERS BECOMES ALMOST CONSTANT. FOR EXAMPLE THE RATIO OF ALL OTHER TANKERS TO THE N3N FAVORS THE N3N UP TO 6-8 TRIPS AFTER WHICH THE RATIO BECOMES ALMOST CONSTANT; THE RATIOS OF THE F7F AND TBM TO THE C-45 FAVOR THE C-45 UP TO ABOUT FOUR TRIPS; THE RATIO OF THE F7F TO THE TBM FAVORS THE TBM UP TO 2-4 TRIPS.

(2) WITH NUMBER OF TRIPS TO THE FIRE (N) CONSTANT, INCREASING DISTANCE TO THE FIRE (D) FAVORS THE LARGER, FASTER TANKERS.

EXAMPLES OF HOW THE INDEXES IN TABLE 5 WERE CALCULATED ARE AS FOLLOWS:

EXAMPLE #1:

$$C.I. = \frac{VN}{\left[\frac{120\,ND}{R}\right] + \left[T\,(N-1)\right]}$$

N3N

LET V = 200
N = 4
D = 20
R = 90
T = 6

$$C.I. = \frac{200 \times 4}{\left[\frac{120 \times 4 \times 20}{90}\right] + \left[6\,(4-1)\right]}$$

$= 6.4$

F7F

LET V = 800
N = 4
D = 20
R = 180
T = 15

$$C.I. = \frac{800 \times 4}{\left[\frac{120 \times 4 \times 20}{180}\right] + \left[15\,(4-1)\right]}$$

$= 32.6$

$$C.I.\ RATIO\ \frac{F7F}{N3N} = \frac{32.6}{6.4} = 5.1$$

THEREFORE IT CAN BE ESTIMATED THAT FOR THE DATA GIVEN, THE F7F HAS A THEORETICAL CAPACITY TO DELIVER 5.1 TIMES THE GALLONAGE OF THE N3N. THIS INDEX CAN THEN BE COMPARED AGAINST THE 1959 CONTRACT RATES OF

$$\frac{F7F}{N3N} = \frac{\$350}{\$\ 95} = 3.68$$

WHICH INDICATES THAT FOR THE DATA GIVEN, THE F7F WOULD BE PRODUCING MORE FOR ITS MONEY, KEEPING IN MIND ALL THE ASSUMPTIONS THAT HAVE BEEN MADE.

EXAMPLE #2:

N3N	F7F
LET V = 200	LET V = 800
N = 6	N = 6
D = 10	D = 10
R = 90	R = 180
T = 6	T = 15

$$C.I. = \frac{200 \times 6}{\left[\frac{120 \times 6 \times 10}{90}\right] + \left[6\ (6-1)\right]} = 10.9$$

$$C.I. = \frac{800 \times 6}{\left[\frac{120 \times 6 \times 10}{180}\right] + \left[15\ (6-1)\right]} = 41.7$$

$$C.I.\ RATIO = \frac{F7F}{N3N} = \frac{41.7}{10.9} = 3.8$$

THUS FOR THE SHORTER TRIP AND MORE SUSTAINED OPERATION, THE ADVANTAGE OF THE F7F OVER THE N3N DECREASES.

* * * * * * *

Len Chatten